SEA
GRANT
PROJECT
OFFICE

OCEAN ENGINEERING
SUMMER LABORATORY
SUMMER 1971

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
AND
MAINE MARITIME ACADEMY

Prepared by students under the supervision of:
Professor Damon Cummings – M.I.T.
Professor David Wyman – M.M.A.

Massachusetts Institute of Technology

Cambridge, Massachusetts 02139

Report No. MITSG 72-3
October 18, 1971

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Administrative Statement

The Ocean Engineering Department and Maine Maritime Academy offered this Ocean Engineering Laboratory for undergraduate students in both schools for the first time during the Summer of 1971. Support for the subject was provided by the M.I.T. Sea Grant Program and Maine Maritime Academy. This report is intended to serve not only as a description of what was done, but primarily as a guide for those persons and institutions who intend to initiate similar programs. The existance of such a guide would have been of great value to the students and faculty who initiated this program and it is hoped that it will be of use to others. For this reason, daily logs and diving procedures are included as well as technical descriptions.

The printing and distribution of this project report, organized by the M.I.T. Sea Grant Office in cooperation with Professor Cummings, is made possible in part with funds from a grant by the Henry L. and Grace Doherty Charitable Foundation, Incorporated, to the M.I.T. Sea Grant Program. Further funding was provided by the National Sea Grant Program, GH-88, and M.I.T.

Dr. Alfred A. H. Keil
Director

October 1971

PARTICIPATING STUDENTS

Maine Maritime Academy

George Benson
Jonathan Blackwell
Robert Carroll
David Decrow
Mark Dougherty
Thomas Egan
Gardner Fogg
Steven Swindburn
John Uzmann
Harold Webster

Massachusetts Institute of Technology

Robert Biles
Thomas Curtis
Robert Dwyer
Fred Horr
Richard Katz
Robert Lukens
Robert Martin
Robert Powers
John Price
John Schenck
Paul Shapiro
Michael Wargo
Melvin Wolpert
Sandra Zemansky

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The response of experienced and expert personnel in dropping their personal and professional affairs and travelling to Castine, Maine to help out a group of beginning students in the field is extremely remarkable and greatly appreciated.

The greatest recognition and thanks for the success of this program is due Rear Admiral E.A. Rogers and his staff at the Maine Maritime Academy. Maine Maritime Academy provided room, board, boats, space, faculty, ten participating students under the direction of Professor David Wyman, and infinite patience and help to a group of alien and disruptive M.I.T. students and staff for the month of July, purely for their interest in promoting ocean engineering education.

A partial list of those individuals who contributed time and equipment to this program follows:

Dr. Steven Allen of the M.I.T. Draper Laboratory, who contributed time teaching the elements of decompression diving and helping with diver training. He also came to Castine to help out with the diving program and lecture on diving psychology.

Professor Ira Dyer of the M.I.T. Department of Ocean Engineering made a weekend side scan sonar trip with students for the project. He helped with the setup of the laboratory and spent two weeks in Castine working with the students on acoustics.

Acknowledgements (con't)

Professor Harold Edgerton of the M.I.T. School of Engineering made the initial side scan sonar search trip with students from the project, introducing them to search techniques and the use of acoustics. His personal contribution and the loan of equipment and advice from his laboratory is greatly appreciated.

Professor David Michael of the M.I.T. Athletic Department gave a special scuba diving course with emphasis on working with tools and lines underwater and extra open ocean work for students in this project. His cooperation was indispensible and pointed out the value of the Athletic Department's personnel and facilities to this type of engineering program.

Professor Jerome Milgram of the M.I.T. Department of Ocean Engineering contributed time and advice to the M.I.T. students during the spring design and building of instruments and arrived in Castine at the exact moment to solve electronic instrumentation difficulties which were beyond the abilities of those present.

Professor Curtis Powell of the M.I.T. Department of Ocean Engineering loaned his diving gear to the project and drove a carload of students and equipment to Castine. His office did an excellent job of communicating between the project and the M.I.T. bureaucracy while all project personnel were in Maine.

Professor Geoffrey Savage of the Department of Mechanical Engineering at the University of New Hampshire arranged for the loan of the UNH's decompression chamber for the month.

Acknowledgements (con't)

Two of his staff, William Miskoe and Robert Blake delivered the chamber and trained the students in its operation during their vacation.

Captain William Searle and his associate, Lt. Commander Herman Kunz, both formerly of the U.S. Navy, spent a week in Castine educating and helping students with search and diving operations. The association with these two experienced and enthusiastic people contributed tremendously to the educational value of the program.

Professor John Edmond of the Department of Earth and Planetary Sciences analyzed water samples from Penobscot Bay, using equipment not available to the students in Maine. He also provided information on seawater analysis methods which were invaluable for the analysis of water samples at Castine.

Mr. Sloan Hodgson of Woods Hole Oceanographic Institution provided a bathythermograph and Nansen bottle, which were essential for the students' water sampling program.

Mr. George Shapiro of Westinghouse Electric Corporation arranged the loan of a Westinghouse oscilliscope, frequency counter and signal generator without which this project would have come to a standstill as will be apparent on further reading of this report.

The project was partially funded by the National Sea Grant Program, National Oceanic and Atmospheric Administration, Department of Commerce through Coherent Area Project Grant, GH-88.

Professor D. Cummings
September 1971

INTRODUCTION

The purpose of this Summer Laboratory Project was to give students primarily interested in ocean engineering first hand experience in design and implementation of projects in the marine environment. This included understanding and solving problems occurring with the operation of equipment in rough, salty and polluted waters, the problems of navigation, moorings, stability, diving and underwater search, and the interpretation of data.

The laboratory was also an educational experiment in the sense that beginning M.I.T. students, to a great extent freshmen and sophomores, were asked to conceive, design, and construct equipment and develop techniques for their work. The M.I.T. students were in charge of their individual designs from conception to use, but were given the assistance of Maine Maritime students for final machining, welding, assembly and operation of equipment. This association and responsibility for individual projects worked out to the benefit of students from both schools.

The laboratory was designed to help students individually and collectively draw upon their classroom experience to create projects of their own design to solve some particular ocean engineering problems.

The overall goals set for the project were:

(1) Search for and try to recover a sailboat belonging to the Maine Maritime Academy which sank in Penobscot Bay last summer. This required study and design work in sonar,

precise navigation, search patterns, diving, bottom drags, and boat handling.

(2) Gather data on currents, water movements, and pollution dispersion in the Penobscot Bay area of Maine. This required instrumentation for the measurement of current, both surface and subsurface, the accurate determination of tidal height, chemical and biological analysis of water samples, gathering of same, and the design and construction of data analysis systems.

This report is intended not only as an indication and evaluation of what was done, but also as a guide to those with an interest in establishing similar educational programs.

Richard Katz
13.90
September 1971

CONCLUSIONS AND EVALUATION

The opinion of all who were involved with this project, students and faculty of both M.I.T. and Maine Maritime Academy, visiting faculty, and consultants was that this program served an educational purpose that is essential early in the students' Ocean Engineering education. All hands were exposed to the myriad of problems encountered in attempting to apply theory and classroom experience to equipment and procedures that must work at sea without the enormous expense and pressure of full scale industrial or government projects. The usual mistakes were made in an environment where they could be dealt with without cost or loss of essential data and the lessons were learned. Remarkably enough, some of the equipment designed and built and the data collected may be of ultimate value; however, this was not the primary aim of the program.

The enthusiasm, cooperation, and accomplishments of the Maine Maritime Academy students and faculty were vital to this program. The ten Maine Maritime students were assigned to help M.I.T. students with final fabrication of equipment, building of buoys, and mooring arrangements immediately upon arrival in Castine. Their comments indicated that this was the most intensive and purposeful machine, welding, and design work they had been exposed to. Their contribution was immediately effective and indicated a need and use for Maritime Academy trained personnel in the Ocean Engineering field. They understood immediately what the M.I.T. students were trying to do and proceeded to make suggestions, improvements, and hardware the first day. Maine Maritime students were in charge of boat handling for the entire project, and Mark Dougherty and George Benson became experts at the rather delicate maneuvering and station keeping required. Maine students Thomas Eagan and David Decrow designed, built, and operated a Savonius rotor current meter during the program and M.M.A. students Harry Webster and Robert Carrol designed and fabricated the bottom grapnel rig used in searching. The level of cooperation between M.I.T. students and M.M.A. students was extremely high and a project of this type would be far more difficult without their help. Beyond this, the interest developed at M.M.A. in Ocean Engineering education and courses will undoubtly have a significant effect, both on the school and ultimately on the field of Ocean Engineering.

The location in Castine is ideal for a one month intensive program where long hours are anticipated and the distractions of Boston undesirable. The facilities and cooperation of M.M.A. are furthermore essential to the program since M.I.T. has virtually no laboratory or marine equipment for Ocean Engineering use. However, the logistical expense in travel and unavailability of specialized equipment is enormous. Especially in electronics, a considerable investment must be made in laboratory and library facilities in the future. The cost in time and travel expense of having to drive to Bangor for everything from a transistor to a piece of 2 x 6 is extremely undesirable. This implies that in the future more investment will have to be made in laboratory facilities and supplies. Without the generous and fortunate cooperation of Westinghouse Electric Corporation in loaning the program an oscilliscope, a frequency counter, and a signal generator, we would have had to send cars to Cambridge nearly every day to do electronics design and modification. The "engineering" in the wilderness" concept was useful and performed its function, but without a certain amount of basic supplies and facilities time and money is wasted.

In the future, it would be desirable to start Maine Maritime students on their own projects long before the summer program starts. They proved themselves entirely capable of and interested in carrying out independent work in support of the program. This would have been done this year if the faculty had realized the capabilities and enthusiasm of the Maine Maritime students.

The M.I.T. students involved in this project have gained a great deal of educational experience in a short time and early enough in their careers to guide their future choices of academic subjects at M.I.T. and to make their academic curriculum far more meaningful. The interest developed in electronics, machine design, instrumentation, and computer technology is extremely high. The comment of the one sophomore who had taken an electronics subject was that, "I would like to take it again. I would learn it this time."

Most of the M.I.T. students involved had never designed or built anything before this project. Their attempts at drawing, selecting materials and sources of supplies, dealing with machine tools, and making things water-tight were marvelous to behold. However, by the time the project was ready to start for Maine, the students had become rather competent in all these fields. Their experience will be of immense value in future project and thesis work. It must be remembered that these students were primarily freshman and sophomores and have gained a terrific lead on the classes before them. One of the greatest difficulties with senior and graduate student experimental work is that the students do not know how to design, build, or even purchase anything. The students who participated in this project are well beyond that level. They can be counted on to work efficiently and with competence on experimental apparatus and to conduct experiments with intelligence. They are aware that nothing works at sea without much design, thought, and testing and will not waste time with hopelessly underdesigned apparatus. They have launched equipment from boats and have dived to watch it operate in, or be operated on by, the sea.

For the purpose of offering advice to those who will be initiating educational projects of this type in the future, the author feels that the following points are most essential:

1) Each student must be in charge of design, construction, placement, operation, data analysis, and report of his own equipment. The experience of working through these steps, dealing with purchase orders, machine shops, drawing tools, and electronics is far more important than the ultimate professional quality of the apparatus.

2) It does not matter if the project due to #1 above becomes rather sophisticated and diversified. Concentration on one type of instrumentation for one specific purpose would undoubtably lead to better scientific results with far less work by faculty and students. However for the educational goals intended it is far preferable to diversify the program so that each student has his own project. The students will work extremely hard to get their own thing working, and the faculty just has to be patient.

3) It does no harm if the individual projects are a bit over ambitious. In the time scale involved, it is extremely unlikely that a freshman or sophomore can develop a well engineered piece of equipment of the type that takes commercial engineering firms years to perfect. However, if it works at all, that is plenty. It is the lessons learned along the way that are important.

4) The time-scale and location are vital to success. Seven of the M.I.T. students involved, started on Their projects in February 1971 on a part time basis. This was really too late. Full-time work and more was required by all M.I.T. participants preparing equipment in Cambridge during the month of June. The month of August was spent essentially half-time writing this report. Thus, what appears to be a one month laboratory is in fact, a schedule as follows:

February-May:	Part time planning and design of apparatus
June:	Full-time redesign and building
July:	Actual operation
August:	Data analysis and write-up

In the future, students should be started on planning and design, construction, and preliminary testing be done at M.I.T. where the facilities of the Institute and Cambridge are available. A month of actual operation is ideal, Any less would not allow meaningful work to be accomplished and any more would totally exhaust the students and particularly the faculty. A location for the actual operation well away from Boston is vital and Maine Maritime Academy with its equipment, faculty, and students is ideal.

5) It is important that the students write the report. If you have written a full-scale research report as a freshman or sophomore, you are getting a real head start on future work.

6) It is important the the students be encouraged to learn to dive and to work in as well as on the water. A special course was held by Professor Michael of the Athletic Department for this purpose. It is far simpler in the time-scale involved to design equipment to be placed and monitored by divers than to design apparatus that can be dropped and left. As the students become more sophisticated in their design and construction of apparatus the need for diving will decrease, but the author hopes not completely. A major goal of this project is to familiarize the students with the ocean environment. In the same way that sailboat racing and working from boats are excellent training for understanding the surface environment, diving to place and monitor equipment and watching the effect of the ocean on one's apparatus is an excellent way to learn about the subsurface eironment. Many visitors commented that they felt there was an overemphasis on diving; however, the author feels that this is an essential, if minor part of the project. It should be reiterated that a great deal of the total time was spent in Cambridge designing,

building, planning, and reporting which is not apparent to the visitor during the project itself.

It was obvious to all concerned with this project that this laboratory was an extremely important, and probably essential part of the education of both M.I.T. and Maine Maritime Academy students. The Ocean Engineering Department at M.I.T. will find it extremely difficult to offer an undergraduate program without a subject of this type. The facilities and environment at M.I.T. are not suitable for the execution part of the program and the cooperation of Maine Maritime Academy is essential. M.I.T. could offer a similar program on Massachusetts Bay, but only at considerable cost in the educational value of having to plan for operations away from the home facilities and without the intensive program encouraged by isolation in Castine.

Professor Damon E. Cummings
September 1971

PLANS FOR SUMMER LABORATORY - 1972

Planning has been initiated for a continuation of this laboratory subject in 1972. Maine Maritime Academy has expressed their desire to participate again. Work will commence at M.I.T. in the fall term of 1971 as a Freshmen Seminar for new students and under the M.I.T. Undergraduate Research Opportunities program for returning students. Some financing is available through Undergraduate Research Opportunities program to reinforce reduced Sea Grant funding.

Many of the continuing M.I.T. students wish to improve and modify their instruments for the measurement of currents and tidal height. Much interest has been expressed in developing data for a numerical model of one of the smaller estuaries in Penobscot Bay, such as the Bagaduce River. This will involve rather sophisticated computer technology and the students intend to take computer science subjects in the fall to increase background in this area.

The need for a more sophisticated, automatic data handling system was apparent in this summer's work and the students involved intend to develop a direct magnetic tape to computer system to simplify this problem. The possibility of a radio-telemetry system such as was developed for the Sea Grant Massachusetts Bay Project will be investigated.

During the search effort, it was obvious to the students that a high resolution instantaneous read-out electronic navigation system would be of great value in search and charting work. The possibility of developing a short range hyperbolic navigation system similar to Loran or Ray Dist will be investigated by the students. The students involved intend to concentrate on electronics subjects in the fall.

It was also noted that in conjunction with the navigation system an automatic station and path holding control system for the sonar boat would be of great value. The boat handling problem of holding a precise transit line with variable cross currents and wind would be greatly simplified by such a control system linked to the electronic navigation system. Several members of the Deep Submergence Rescue Vehicle Group at the Charles Stark Draper Laboratory have offered their help and advice on this scheme.

The lack of a sufficient side scan transducer was felt and one student has decided that he can build a transducer that will do a better job.

The primary needs for laboratory equipment, space at M.I.T. and a Boston based vessel for testing equipment and techniques are slowly being worked out. Professor Dyer has offered to contribute a recording fathometer and Professor Cummings has bought a 36 foot boat in the absence of M.I.T.

or Sea Grant funding. It is anticipated that the necessary electronics equipment can be built, begged or borrowed in the fall.

Professor Wyman of Maine Maritime Academy intends to offer a seminar course during the school year in Castine, parallel and in conjunction with the program at M.I.T. The Maine students will, therefore, be ready to go with their own projects in support of the program next summer. Trips by the Maine students to M.I.T. to coordinate efforts are planned.

It is hoped and anticipated by both the M.I.T. and Maine Maritime Academy faculty participants that this subject will become a permanent part of the curriculum for both schools. Funding is, however, not arranged through Sea Grant beyond 1972. It is suggested that with the help of the Undergraduate Research Opportunities program and some M.I.T. general support the program can be continued beyond the Sea Grant expiration date. The greatest costs for this project occurred in the areas of travel and living expenses for participants and visitors, and in student tuition support. It is completely unrealistic to plan on this type of project without tuition support. The students, the majority of whom are receiving insufficient financial aid for their studies, could not possibly make ends meet if they had to pay tuition as well as skip summer employment. An effort must be made to arrange tuition support for this program beyond 1972. The visiting faculty and participant travel and living expense can be cut down, but in the case of visiting faculty at considerable cost to the educational value of the project and increase in the participating faculty work load. The participant travel expense will decrease in the future with more advanced facilities and equipment in Castine. The contribution of Maine Maritime Academy in donating room and board for the M.I.T. students is, of course, vital to the financial viability of the program.

M. Wolpert
13.90
September, 1971

INSTRUMENTATION

General

One of the chief objectives of this laboratory subject was to introduce students, both theoretically oriented M.I.T. students and hardware oriented Maine Maritime Academy students, to the challenge of designing and constructing equipment for use at sea. The intention was to create self designed and built equipment which required mooring and buoy systems, hydrostatic and hydrodynamic considerations, electronics, and mechanical construction. It was decided early in the project to make the instrumentation systems simple at the sacrifice of miniaturization and the ability to do everything from the surface. Since one of the objectives of the subject was to accustom the students to working underwater at moderate depths, no effort was made to design the equipment for installation without divers. In this way, the students quickly became aware of the cobweb tendency of complicated mooring systems, the effect of pressure on styrofoam underwater floats, the tendency of air bag flotation to expand and contract with the tide, the ability of lines to seek and attack rotating devices, the tendency of algae to grow right in the photocell light path, the perversity of underwater electronics, and a myriad of similar difficulties that might as well be encountered early in an Ocean Engineering education.

The instrumentation was aimed primarily at obtaining preliminary information on the motion of water in the Castine area of Penobscot Bay, and the associated motion and dispersion of pollutant waste from cities and industries in the area. Five different systems were developed for the determination of tidal current strength. One vane and variable capacitance instrument was made for current direction recording. Systems were established for taking water and bottom samples. Included as part of the instrumentation is a section on underwater photography since a great deal of experiment and analysis went into obtaining useful photographic information underwater in the bad visability situation prevalent in Penobscot Bay.

The remarkable and gratifying aspect of this effort is that by the input of long hours, endless diving, and boundless enthusiasm, most of the equipment was coaxed into action by the end of the month in Maine. Although commercial design and production was definitely not an objective of the program, a couple of the systems developed show possibilities as inexpensive alternatives to commercially available apparatus. This will require considerably more engineering design and analysis effort, but that is intended by the participants.

Professor Damon E. Cummings
September 1971

SURFACE INSTRUMENTATION

The purpose of this instrumentation was to keep a data record from any one of the meters as conveniently useful as possible along with containing the meter's power supply. This meant constant data taking with infrequent need for maintenance. Other desirable features included some type of waterproof (or at least water-resistant) housing, low power consumption, dependability, and simplicity.

The choice of a recording instrument had to involve a great deal of compromise from the ideal. Our solution was the use of a cassette type tape recorder. This offered several advantages. Cassettes allowed ease in changing tapes. The cost of a recorder was low, $20.00. A tape recorder is a sturdy instrument as compared with a chart recorder because there are so few moving parts. If large quantities of data are taken, the material can be fed into a computer for complete analysis through electronic systems rather than manual. For small quantities of data, however, where much of the work is done manually, a chart recorder would be much more convenient. Also, a chart recorder allows a longer recording period per maintenance trip. Using the longest reliable cassettes, one can get only 45 minutes of recording time on one side of a tape.

The impossibility of changing tapes every 45 minutes necessitated the use of a timer to turn the recorder on for a brief sampling period at a given time interval. We decided

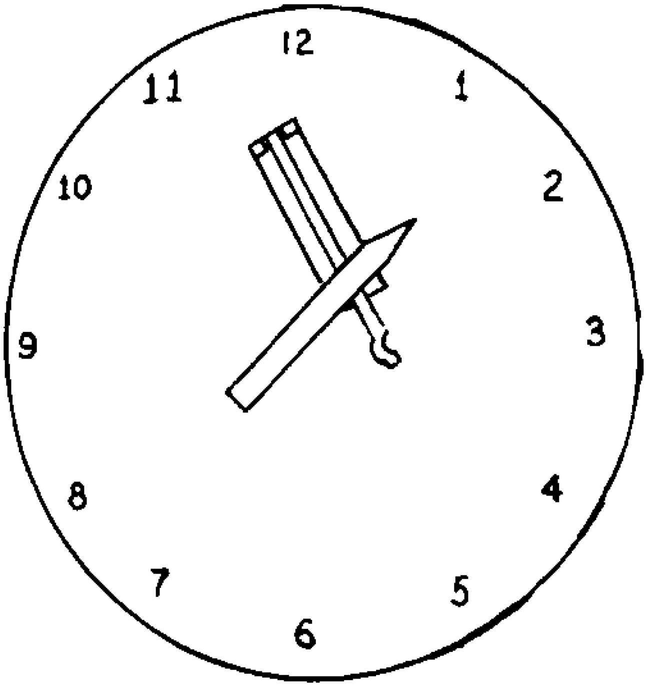


FIGURE 1

that we wanted an on-time of 25 sec. every 1/2 hour. This gave us 2 days of recording without maintenance. The timer was a windup alarm clock. We removed everything from the drive train except for the minute hand to increase the available power to that hand. We first mounted a reed type microswitch vertically on the clock face so that as the minute hand hit the switch, it closed it until the hand passed over the switch, when it returned to normal. Both ends of the hand hit the switch, so it turned on twice an hour (see Figure 1).

This system worked fine in the lab, but was not solid enough to withstand placement in a buoy exposed to seas. The on time was adjusted by bending the ends of the minute hand up and down. The tolerances required were far too close to be achievable under rough conditions. This was remedied by removing the hour hand and mounting a plexiglass cam on the shaft. The switch was then mounted horizontally. The on time could be adjusted to within 2-3 seconds by rotating the switch so as to bring the reed closer to or farther from the cam. There were never any problems with this timer (see Figure 2).

For mounting the instrument system and keeping it dry, we used a double-hulled, fiberglass ice chest, about 15" x 10-1/2" x 12" inside dimensions. Spray did no damage, but it would not have survived more than an instant's total immersion. It was protected from this by being placed in a specially designed buoy, described in a different section

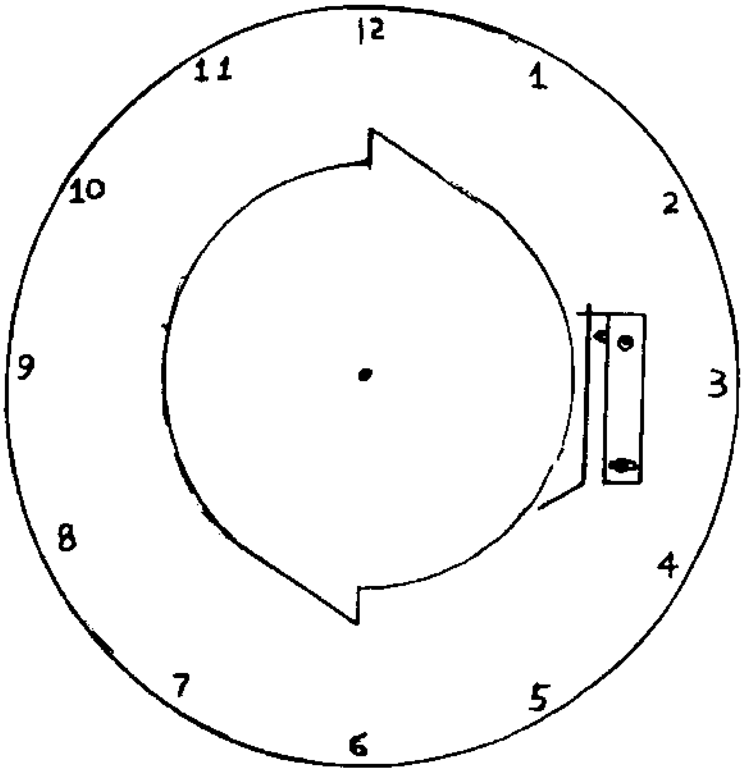
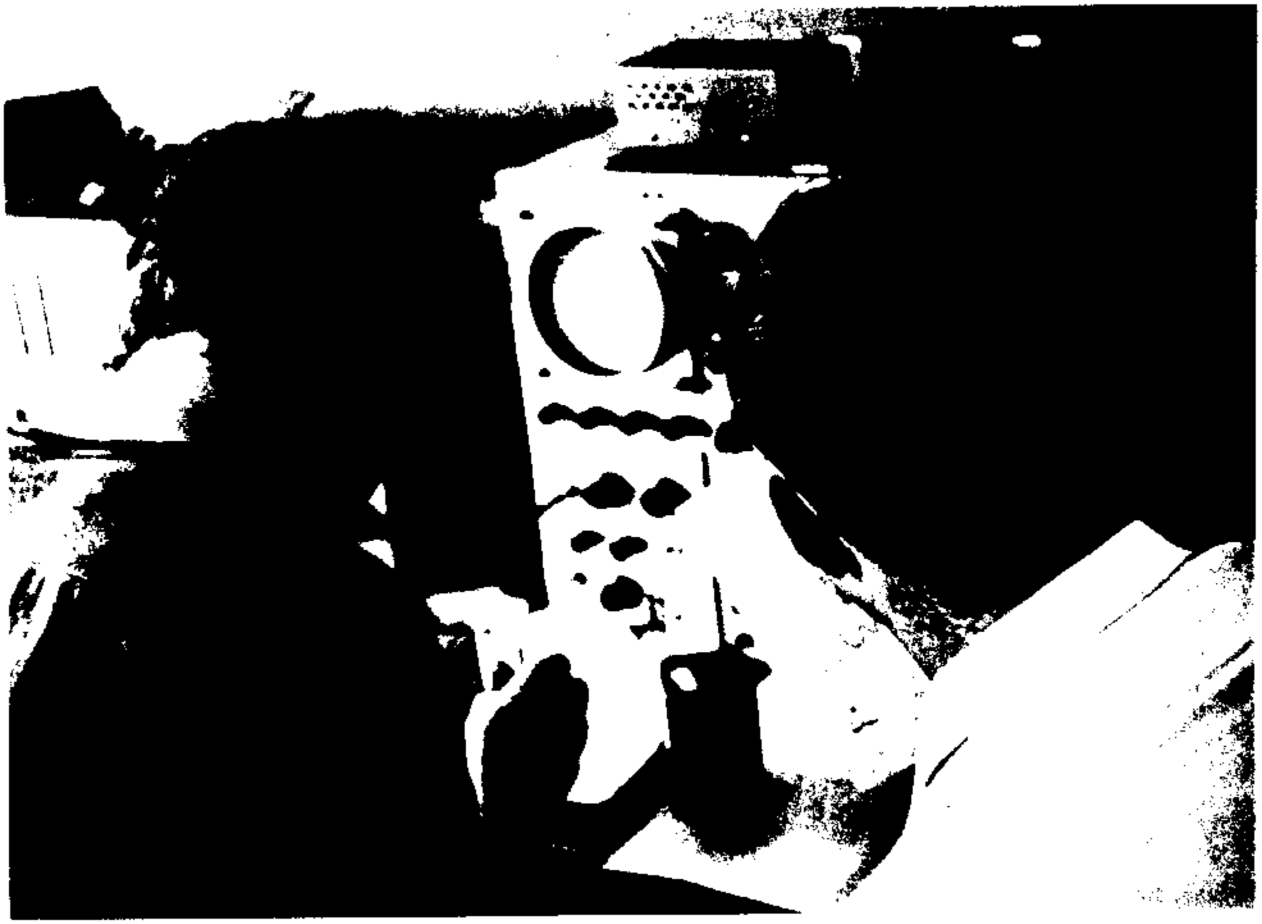
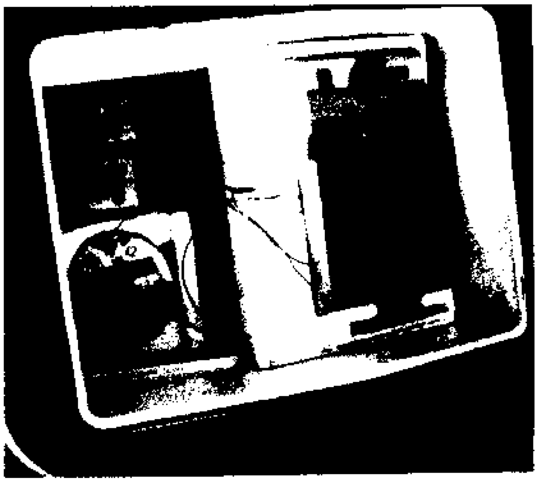


FIGURE 2

SURFACE INSTRUMENTATION



DESIGN OF CIRCUITS



COMPLETE SURFACE POWER SUPPLY, TIMING, AND RECORDING SYSTEM

FIGURE 3

of this report. We covered the bottom of the cooler with a 1" thick piece of styrofoam with many holes punched in it. The instruments rested on this and hence, small quantities of water would do no harm. The instruments were held in place by strips of 1/8" plexiglass about 2" x 3" which were placed in slots cut in the styrofoam (see Figure 3).

There were 3 basic electronic systems, one for the photocell current meter, one for the two beat frequency oscillators, and one for the Savonius rotor. The first one built was for the photocell current meter. This was the most complicated system. The output of the meter varied in frequency from 1/10 cps to 200 cps and hence an audio tape recorder could not record the data directly. The solution was to amplitude modulate the output on a higher frequency carrier wave. Our first oscillator for producing the carrier wave was a transistor siren circuit. We modified it so that th output remained at constant frequency rather than varying greatly like a siren does and then increased the frequency to the desired range, about 3,000 cps.

The power setup in this initial instrument was very complicated. The recorder ran on its own internal batteries. The oscillator and current meter were powered by a pair of 6 volt dry cells in parallel. To turn on two independent systems with a single timer, we used a double pole relay with the timer making and breaking the connection to the windings. All wiring was done directly and nothing was color coded because only one type of wire was available at the time. It was practically impossible to troubleshoot

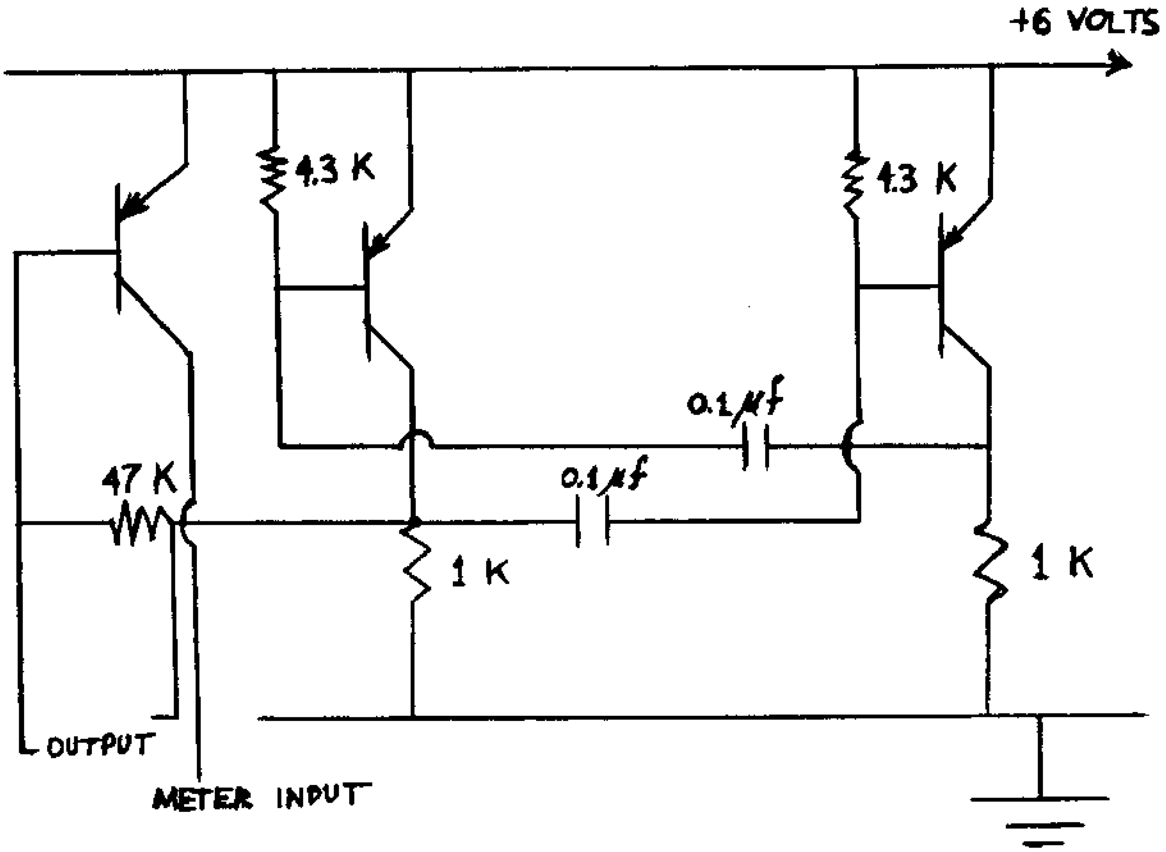
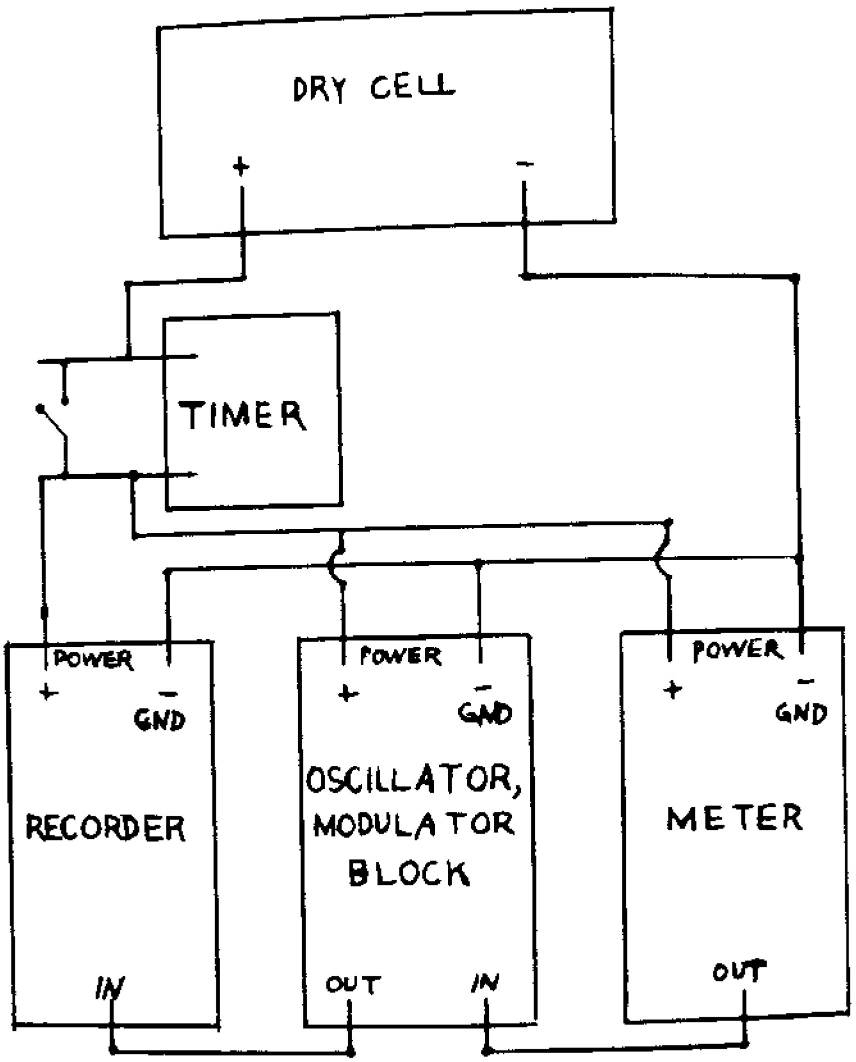


Figure 4


DRY CELL
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−
TIMER
POWER
+
−
GND
RECORDER
IN
POWER
+
−
GND
OSCILLATOR,
MODULATOR
BLOCK
OUT
IN
POWER
+
−
GND
METER
OUT

FIGURE 5

the system. The first improvement was rewiring using vector board and pins and color coded wiring. At the same time a switch was added that could short circuit the timer for testing the equipment. There were also power problems. The relay drew too much power and the tape recorder batteries failed rapidly. We replaced the power supply system with a single large 6 volt dry cell, the biggest we could find. Everything ran off of this. We used plugs and jacks for the tape recorder power supply and input as opposed to direct wiring.

After these improvements, the system worked quite well until the oscillator failed. We then built a new oscillator and proper amplitude modulation system (see Figure 4). After these improvements, the system functioned reliably with no more problems (see Figure 5). The other systems were similar to this one, with minor adaptations for each instrument as necessary.

Paul Shapiro
13.90
September 1971

DATA BUOY

The system design used to obtain current and tide information from underwater required a buoy as a tender for surface recording data. It was necessary to design a buoy which could safely house a recorder, battery, and timing mechanism, plus be easily serviced from the boats that were used for the project.

The prime design criterion was stability of the buoy, for it was very important to protect the equipment and data under any expected conditions. To attempt to design a watertight floating box to house the equipment was considered difficult and impractical. The placing of the equipment a few feet above the surface of the water would make service runs much simpler. Besides the initial placement of the equipment on the buoy and the final retrieval, servicing consisted of changing the cassette tape and winding the clock.

The basic platform of the buoy consisted of a 40" square block of styrofoam, 5" thick, sandwiched between two pieces of half-inch plywood. The density of the styrofoam is approximately 2 lbs./cu. ft., so more than 250 lbs. of positive buoyancy was provided. A superstructure housing was built using two by fours covered with 3/8" plywood. A rectangular box, a commercial ice chest, housed the equipment. The ice chest was placed almost two feet above the water in the plywood superstructure. A vertical, hinged door flush with one side of the buoy made servicing easy, while keeping the equipment protected.

CONSTRUCTION

OF

DATA BUOYS

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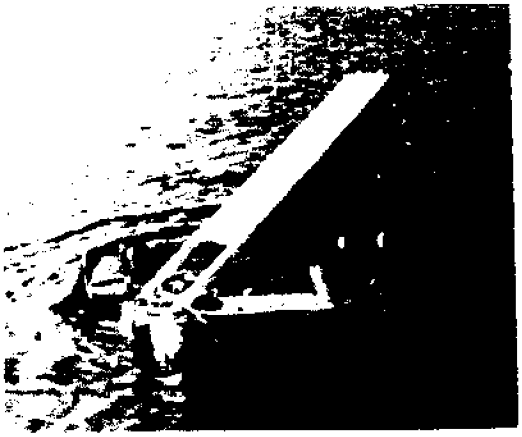


DATA BUOY

ON

STATION

FIGURE 6

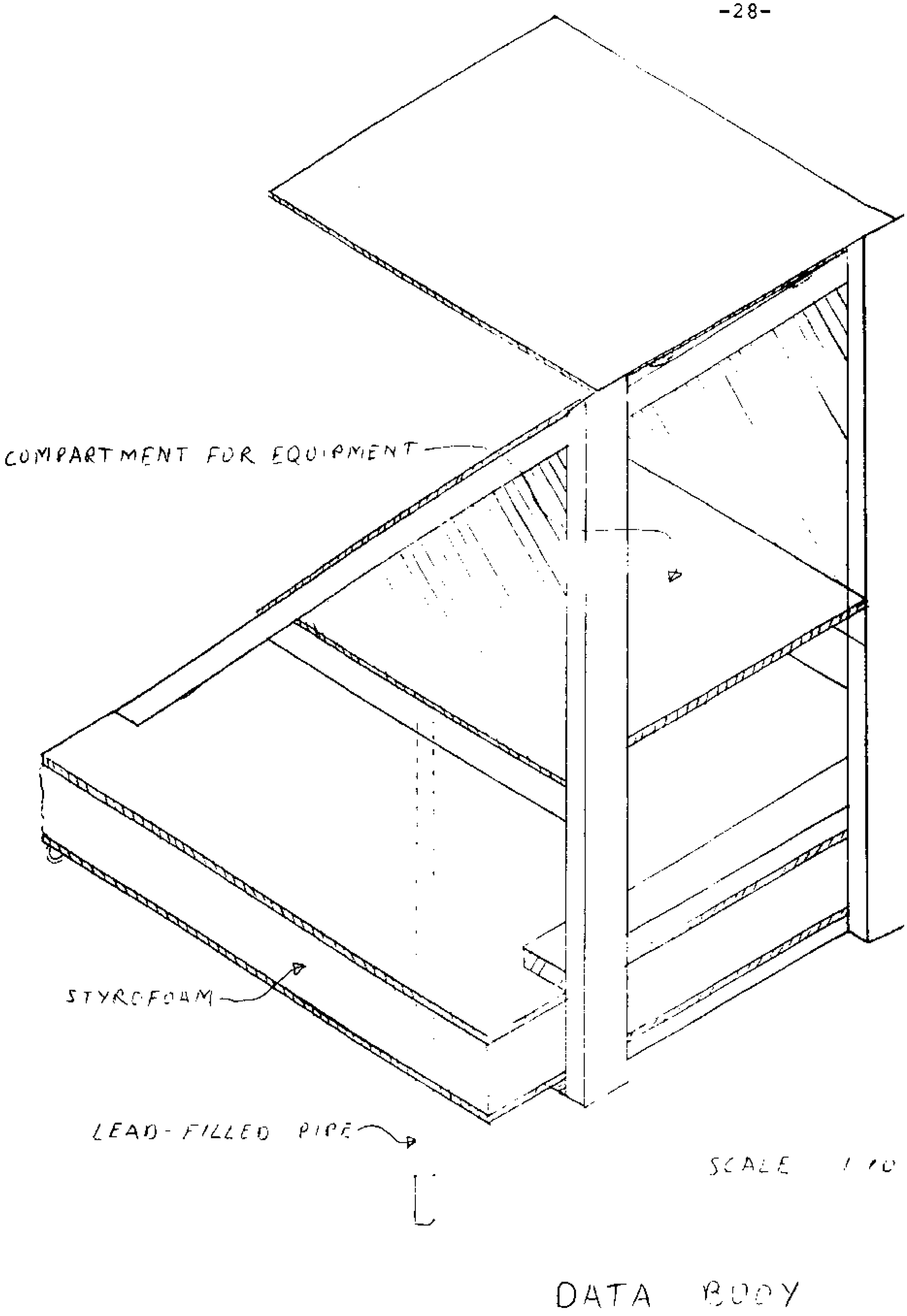

COMPARTMENT FOR EQUIPMENT
STYROFOAM
LEAD-FILLED PIPE
SCALE 1/10
DATA BUOY

FIGURE 7

To offset the high center of gravity caused by the superstructure and the equipment, a lead filled pipe was positioned vertically below the platform. The pipe was placed off-center to counteract for the unsymmetrical shape of the superstructure.

A mooring bridle was fastened to the bottom piece of plywood; it was attached to the side opposite the hinged door to help counteract for the superstructrue weight being off-center and the force of wind. A three point mooring was used to anchor the buoy. The anchoring system consisted of a Danforth anchor and a concrete block attached by line to the buoy bridle.

The buoy, although simple in design and construction, surpassed the designer's expectations. It easily met the requirements of ample stability to protect the equipment and of ease in servicing. Only two buoys were constructed for the summer project, but some plans were made to improve upon the design and build other buoys for the Maine Maritime Academy oceanographic work. The trim of the buoy was the only noticeable deficiency of design. This can be improved by changing the location of the lead pipe, or by increasing the weight.

Fred Horr
13.90
September 1971

VORTEX SENSING CURRENT METER

The development of a current velocity meter which utilizes the vortex shedding properties of a body immersed in fluid was undertaken as one of the individual design projects for the 1971 Ocean Engineering Summer Laboratory

The basis for operation of the instrument is the periodicity of vortex shedding of a submerged circular cylinder resulting in the characteristic vortex pattern known as the Karman Vortex Street. This periodicity or frequency of vortex shedding is directly proportional to the relative speed of the fluid and the submerged cylinder.

The shedding frequency can be expressed in terms of the dimensionless Strouhal number which relates frequency of vortex shedding, diameter of cylinder, and current velocity as:

$$S_n = nd/V$$

The empirical relationship between the Strouhal number and the Reynolds number is shown in Figure 8. From the graph it is seen that the Strouhal number becomes essentially constant for Reynolds numbers greater than 1,000. Below a Reynolds number value of sixty, there is no separation; no vortices form.

The formation of vortices causes forces on the cylinder which are normal to the current flow. If the cylinder is not rigidly attached, oscillations will result. These are often of considerable amplitude if the frequency of vortex shedding approaches the natural oscillatory frequency of the cylinder.

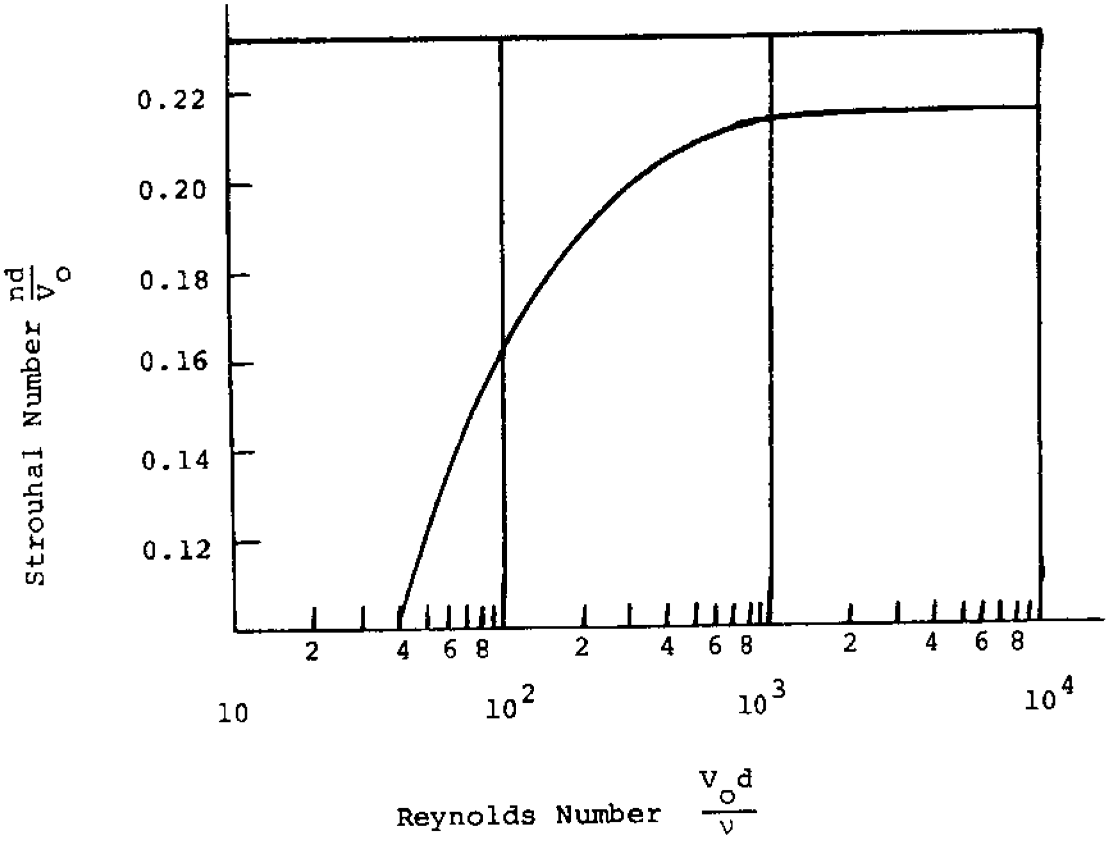

0.22
0.20
0.18
0.16
0.14
0.12
Strouhal Number $\frac{nd}{V_o}$
2
4
6
8
2
4
6
8
2
4
6
8
10
10^2
10^3
10^4
Reynolds Number $\frac{V_o d}{\nu}$

FIGURE 8

As evident from the formula, if there is a cylinder of given diameter, there evolves a characteristic frequency of oscillation for each current velocity, influenced to a small extent by the varying Strouhal number for low Reynolds numbers:

$$n = S_n V/d$$

For higher Reynolds numbers where S_n is a constant there is a strictly deterministic relation between n and V:

$$n = .21\ V/d$$

Thus the detection of the frequency of vortex shedding of a cylinder gives (with proper calibration) a measure of the current velocity.

For the development of a meter using this phenomenon, two approaches to the problem are available.

1) Use a large cylinder to provide the vortex pattern, then sense the changes in the pattern by some electro-mechanical means.

2) Use a small cylinder (wire) such that the vortices shed by the wire in turn cause the wire to vibrate, then count this oscillation, instead of dealing directly with the vortex street.

Initial constraints placed on the instrument by our recording devices and the concurrent desire for simplicity determined the method of attack. Our data recorders were magnetic cassettes operating essentially in the audio range with a stated low frequency limit of about 100 Hertz. Given this frequency and a ballpark velocity of 1 ft./sec, we can use the previous formula to obtain an estimated cylinder size.

$$s_n = nd/V,$$

yielding $n = (.21)(1)/(100) = .0021$ foot.

Thus, to obtain frequencies in the recordable range without involving ourselves in anything but simple electronics, we need a cylinder about .025 inches in diameter. This figure leads to the use of the second method of sensing the oscillations in the vortex street.

To more specifically define the problem; we need to sense the mechanical vibrations of a wire in water and convert these into an electric signal carrying a frequency of sufficient amplitude to be recorded.

Three possible methods developed for the conversion from the mechanical to electrical oscillation:

1) Piezo-electric devices
2) Ceramic phonograph pickups
3) Induction microphones.

Piezo-electric devices are essentially a crystalline material which, when stressed, offer a differential capacitance and thus, a change in voltage across the leads attached to it. The piezo-electric crystals available ranged in size from 1/2 to 2 inches in length, all with an elliptical cross-section with the larger diameter on the order of 1/16 inch. Difficulty arose in making a viable electrical connection as well as a mechanical connection to the vibrating wire which would sufficiently pass the vibrations needed to stress the crystal. The devices proved to be too brittle for handling and probably too brittle for use under any but laboratory circumstances.

Next came the attempt to use phonograph cartridges. Such would seem to be well suited to the purposes, having the correct frequency response and being readily available. Here again, mechanical connection was difficult and the cartridges broke down under use and handling. With further work, either of these methods could yield results, but with a time restriction involved, easier ways were sought.

An induction microphone was stripped of all but its essential parts, leaving only the metal base housing the core from which the leads come. The wire to be immersed in water was soldered to the case at one end, the rest of the wire passing across the face of the microphone as shown:

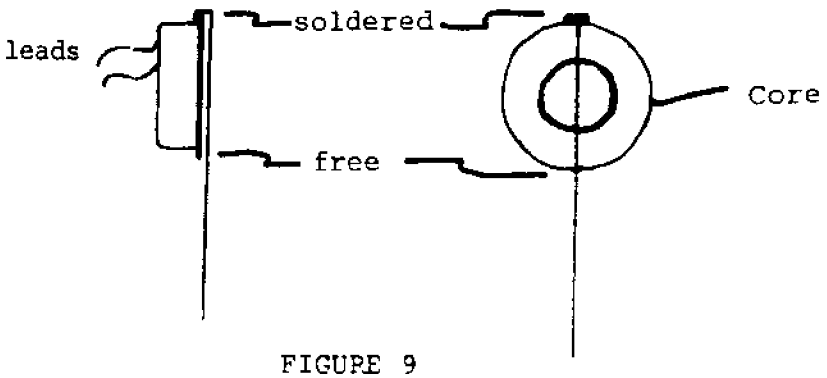


FIGURE 9

This connection proved to be a good transmitter of vibrations. Testing at this point was done using a free water surface. Dragging the free end of the wire through water would yield strong signals, but only in a narrow range. This range was that near the natural frequency of the wire. Closer audio examination of the output signal showed the existence of frequencies related to most low velocities, but these signals were very weak and normally covered by noise or overcome by the natural frequency of the wire.

Two things were done to help accentuate these low level signals:

1) The wire was shortened from an original six inches to about 3 1/2". This shortening was sufficient to raise the natural frequency of the wire to about 350 Hertz, out of the range in which we were interested.

2) A low pass amplifier was put together using the op-amp circuit shown below.

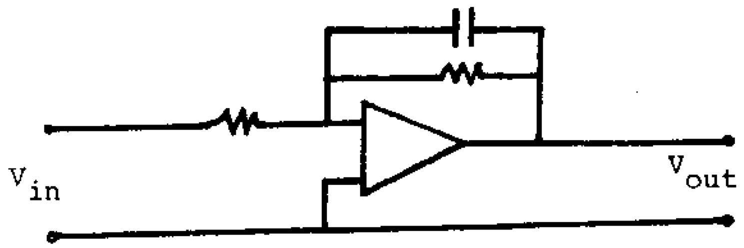


FIGURE 10

With a gain of about 300 to one at 100 Hertz, and an attenuation of high frequency signals, the desired signals could be obtained at a readable strength but still in a very restricted velocity range. The signals ranged in frequency from 60 to 90 cycles, somewhat below the given limits of the recorder, yet, still readable.

All tests to this point were not done in a rigorous manner. No correlation between velocity and frequency was attempted. The goal here was the testing of basic principles, followed by development to the working prototype.

KARMAN VORTEX STREET CURRENT METER

FIGURE 11

The limited success using free surface tests lead to the attempt to make the instrument submersible. A major problem here is the necessity of keeping the wire wet and the microphone and electronics dry, yet, still maintain a usable transmission of vibrations across the water-air interface through whatever material is used to keep the components dry.

The vessel housing the components consists of a plexiglass tube, four inches in diameter and 18 inches in length. The large length is for purposes of pressure equalization which will be explained shortly. The microphone was mounted rigidly in one end in such a way that the wire extended about three inches from the end of the tube. The components making up the pre-amp were mounted adjacent to the microphone, just inside it. Approximately 3" of the tube's length was occupied by these components. The wire extended through a thin neoprene diaphram which was clamped over the end of the tube. Rubber cement provided a seal between the wire and diaphram. This arrangement was found to provide the least attenuation of vibration, provided that the diaphram was properly tuned to put no undue stress on the wire in any one direction (see Figure 11).

Tests were made in the towing tank in an effort to determine what range of response could be expected. The instrument was placed in the water, half submerged with the wire straight down, the upper end of the tube still open. The pressure head developed put considerable stress on the seal and diaphram and caused leakage which aborted the tests several times.

The most successful results of these trials showed a response in the range from about .4 to .6 knots with a differential in frequency which allowed detection of velocity changes to one twentieth of a knot. The trials here were hampered by the interference induced by the vibration of the towing carriage, by the electrical noise from the surroundings and by leakage. Operations at this time were moved to Castine.

Initial work in Maine was directed toward making the instrument totally submersible. The open end of the tube was fitted with a balloon which allows the tube to fill w water, moving inward with the compressed air column. The system should thus, maintain relatively equal pressure on each side of the neoprene diaphram through which the wire extends, lessening the strain on the seal and giving less attenuation of vibration by the neoprene. Trouble was experienced in making the vessel leak-proof for any length of time. While working, the instrument showed less response here than in the towing tank tests. Reasons for this reaction are uncertain. Possibly, detection of the response was more difficult due to less controlled conditions. The permanent working connections had been made including the soldering and sealing of the cable for transmission of data to the surface and power to the instrument. This addition would have caused some lessening of signal strength, but would not be the sole reason for the reduction in sensitivity. The wire could easily be excited in the fundamental and first harmonic modes of oscillation, but driven oscillations outside these ranges were negligable. Changes in wire diameter and length (smaller diameter and longer length) in an attempt to increase response yielded little improvement.

Here an excessive exposure to salt water caused irreparable damage to the electronic components in the prototype. No further attempt was made at making the model work in Castine.

In considering any further work on a meter of such a configuration one must make improvements in several specific areas. A primary concern would be the effective recovery of the frequency induced on the wire by the vortex shedding. The methods used have potential but are extremely rough. They require the protection of the sensing components from the sea water in which the wire operates. This requirement brings with it all the resulting problems of pressure differentials and leakage.

There exists the possibility of using an oil bath to protect the electronics of the instrument. This method would more certainly insure corrosion proofing and be less effected by pressure changes than a chamber containing air which is pressurized or uses some type of equalization like that attempted. Ideally, a way should be devised to pick up the vibrations which does not require isolation from the water. The problems of transferring vibrations from one medium through a membrane to another medium would thus be bypassed.

Essentially, most difficulties came from the fact that the energy imparted to the wire by the vortex street was very small, thus the amplitude of vibration (aside from that at resonance) was very small and hard to detect. Further work could be helped by introducing more exotic shapes than that of a circular cylinder and hopefully in this way, deriving more energy from the formation of the vortices.

If one were not restricted to a certain range of frequencies as we initially were, the use of larger bodies to provide the vortex pattern becomes not only feasible, but attractive. The larger body gives a vortex pattern which is larger and easier to detect since it carries more energy. A sensor of some kind could be positioned in the wake of the body. The oscillations of this sensor should be of considerable amplitude due to the scaling up of all the parameters. The effect of this increase in size would be a reduction in frequency. For a cylinder of about four inches in diameter, the frequency of vortex shedding at one foot per second is about 6/10 of a cycle per second. Detection of the movement of the sensor can be accomplished by the juxtaposition of a magnet on the moving part and a reed switch on a stationary part of the sensor. This combination bypasses the need for transferring a vibration from water to a pickup which only works in air and should prove to be workable.

Robert Lukens
13.90
September 1971

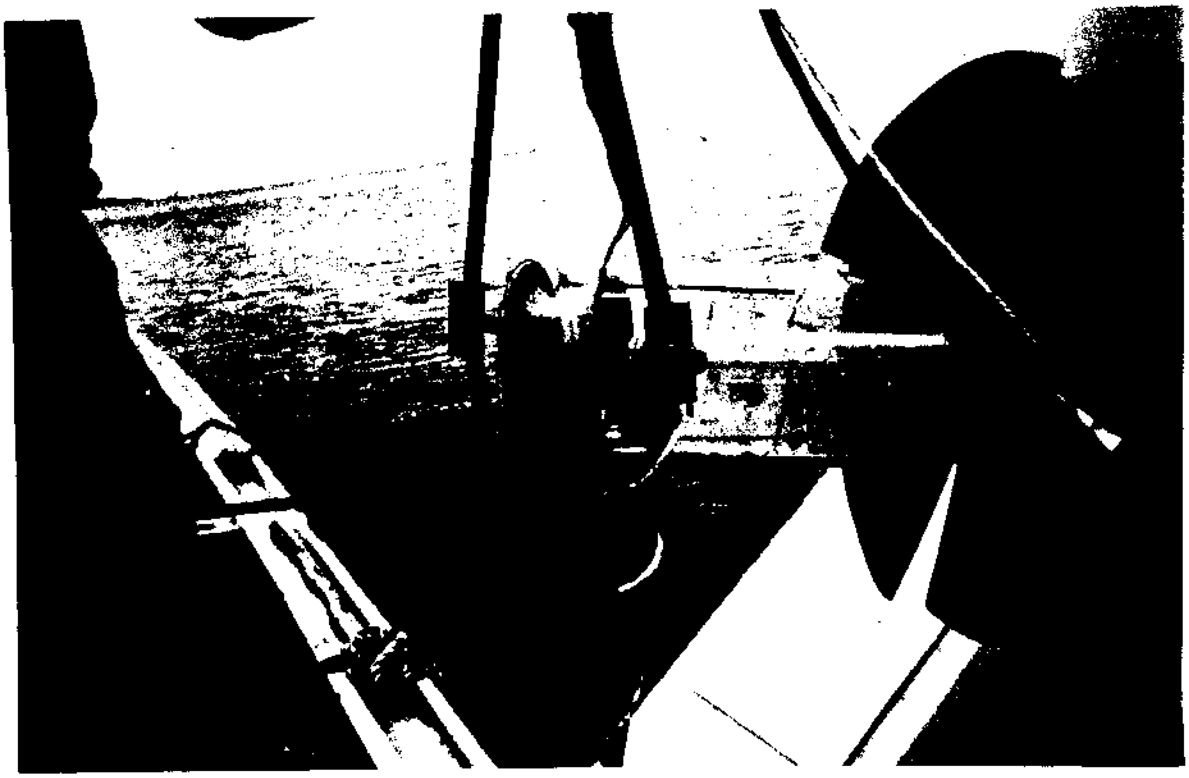
PROPELLER CURRENT METER

In the design and construction of this current meter, there were several requirements to be considered. These had to do mainly with the environment in which the instrument was to operate and with the means for drawing the necessary information from it. The most important and ever-present consideration was that it must operate in salt water at a variety of depths, ranging from just below the surface to 70 feet. It must be capable of accurately and consistently measuring and recording current speeds from very slow to fairly fast (0.1 to 2.0 knots) and it must be sturdy and reliable.

Investigation began with the basic concept of a propeller operated device that would somehow generate an electronic signal at a frequency dependent upon the current speed. The first ideas included a cam or magnet on the rotating propeller shaft which would trip a switch once, or several times, per revolution. The drawback of these ideas was the necessity of direct mechanical contacts, either between the switch and the tripping mechanism or within the switch itself. Our respect for the amazing corroding and fouling abilities of salt water disqualified these ideas. Electrical contacts could be ruined easily and, even if sealed from direct contact with water, mechanical failure could occur and render them inoperable.

The arrangement finally chosen incorporated a light and photocell. A flywheel attached to the propeller shaft

INSTALLATION OF PROPELLER CURRENT METER



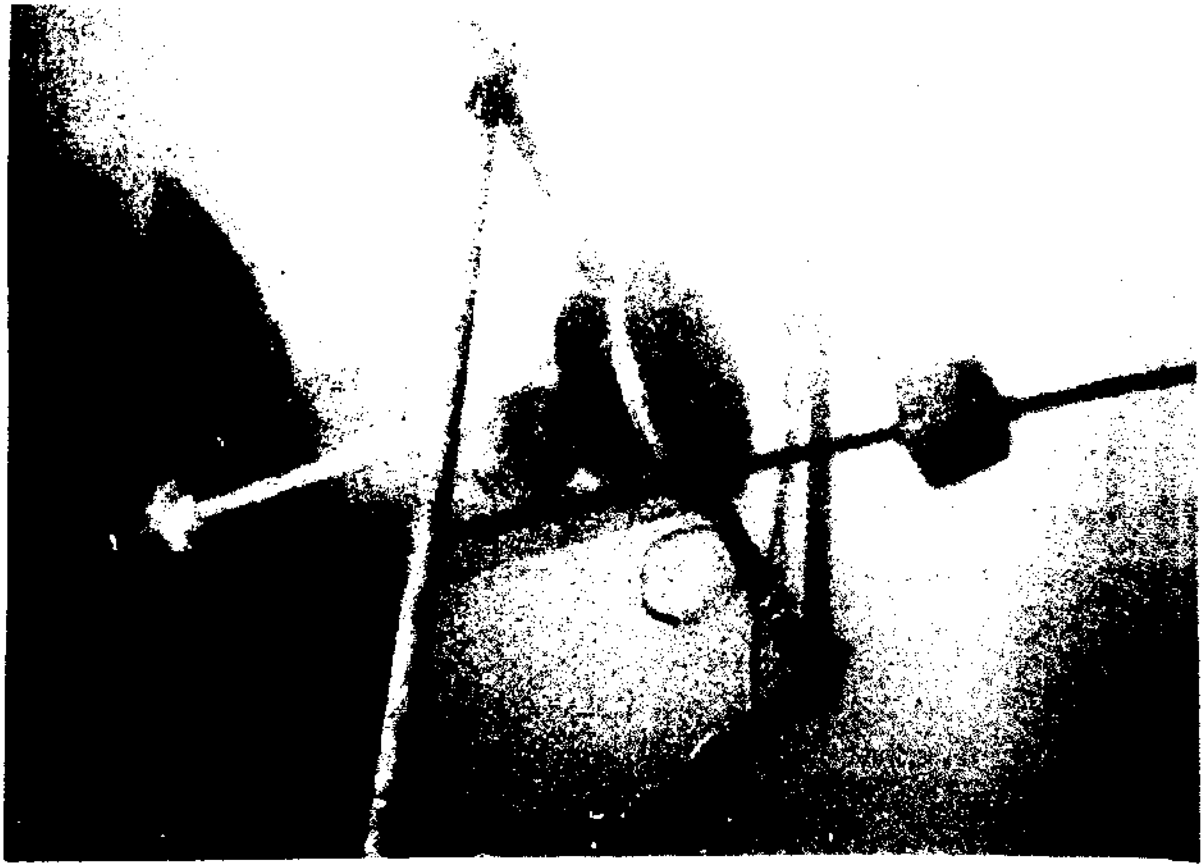


FIGURE 12

would have holes at intervals around its circumference; thus, the light beam would be transmitted and interrupted as the shaft rotated, and the photocell would be activated. This mechanism was favored as it had been incorporated previously in a similar way by the Instrumentation Laboratories. Also, the need for mechanical contacts was eliminated, and the necessary components could be sealed from water easily.

Electrical Circuit

A self-contained light source and sensing device were necessary as there was no other feasible way to direct light of appreciable intensity at depth. A Monsanto infrared emitter was used as the light source. The photocell was a Crystalonics "Fotofet", an infrared sensitive field effect transistor. It was chosen because of its small size and quick response time, as signal frequencies in the audio range were originally desired to facilitate the input of signals into a tape recorder. See Figure 13 for the circuit diagram.

The signal was output as pulses of voltage between the FET source lead and ground. Low rotational speed of the propeller in slight currents prevented the generation of audio frequencies and required that these signals be amplitude modulated with a 3 kHz oscillator and then recorded on a cassette tape recorder. The power source was a six volt "hot shot" battery. The oscillator, recorder, and battery were located in a surface buoy. Hydrophone cable was used a conductor from the instrument to the buoy.

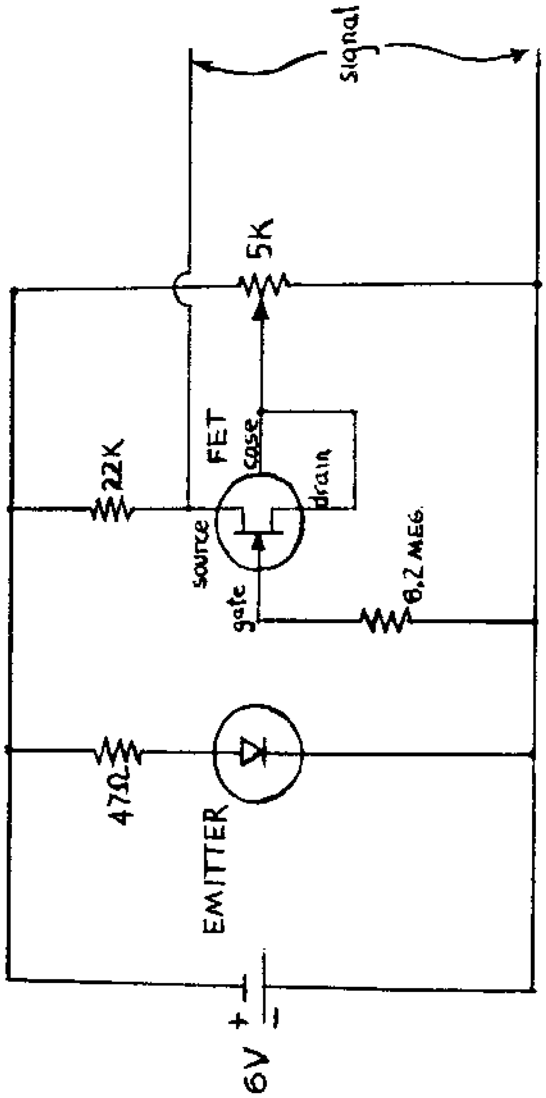

Signal
5K
FET
case
drain
22K
source
gate
8.2 MEG.
47Ω
EMITTER
6V
+
-

FIGURE 13

Shaft and Bearing Unit

The shaft and bearing unit were machined and assembled as shown.[*] The base plate and flywheel were made of Lucite (plexiglass), chosen for its non-corrosive qualities and neutral buoyancy. The bearings and thrust bearings were low-frictional Delrin and the shaft was nylon. Sixty holes were drilled around the circumference of the flywheel to transmit the infrared light.

The container for the electronics was a three inch diameter Lucite bar turned on a lathe and milled flat on one side to attach it to the base plate. The inside surfaces of the flywheel slot were polished smooth to transmit the light more efficiently. As it was necessary to keep the circuit dry, O-ring seals were used on the two end caps. The seals were successfully tested with external pressure of 75 psi; this is the pressure at the depth of 150 feet, far deeper than the instrument was intended to go. The three wire leads were led through one end cap and sealed with epoxy.

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[*] See Figures 14, 15 & 16.

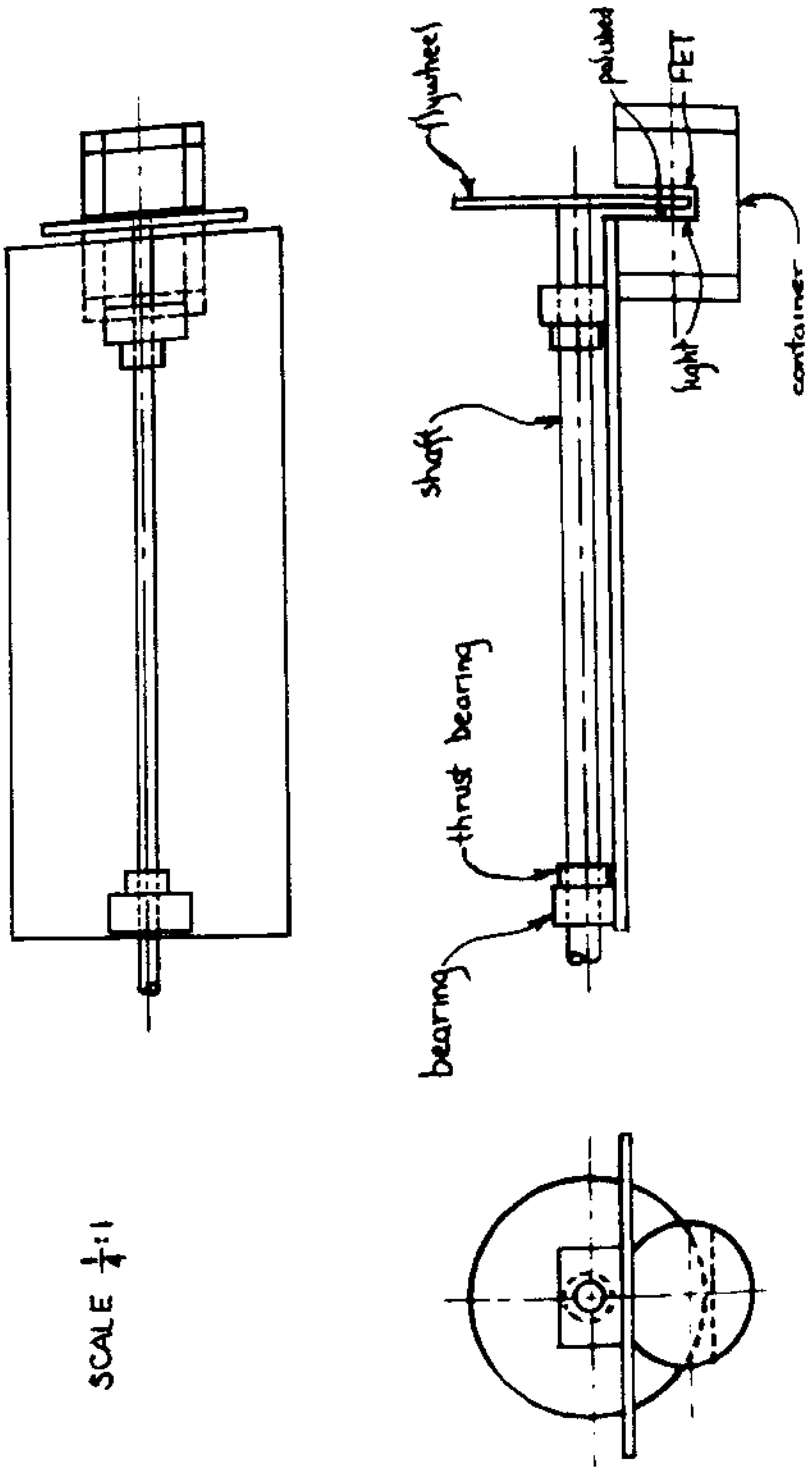

flywheel
polished
FET
container
light
shaft
thrust bearing
bearing
SCALE $\frac{1}{4}$:1

FIGURE 14

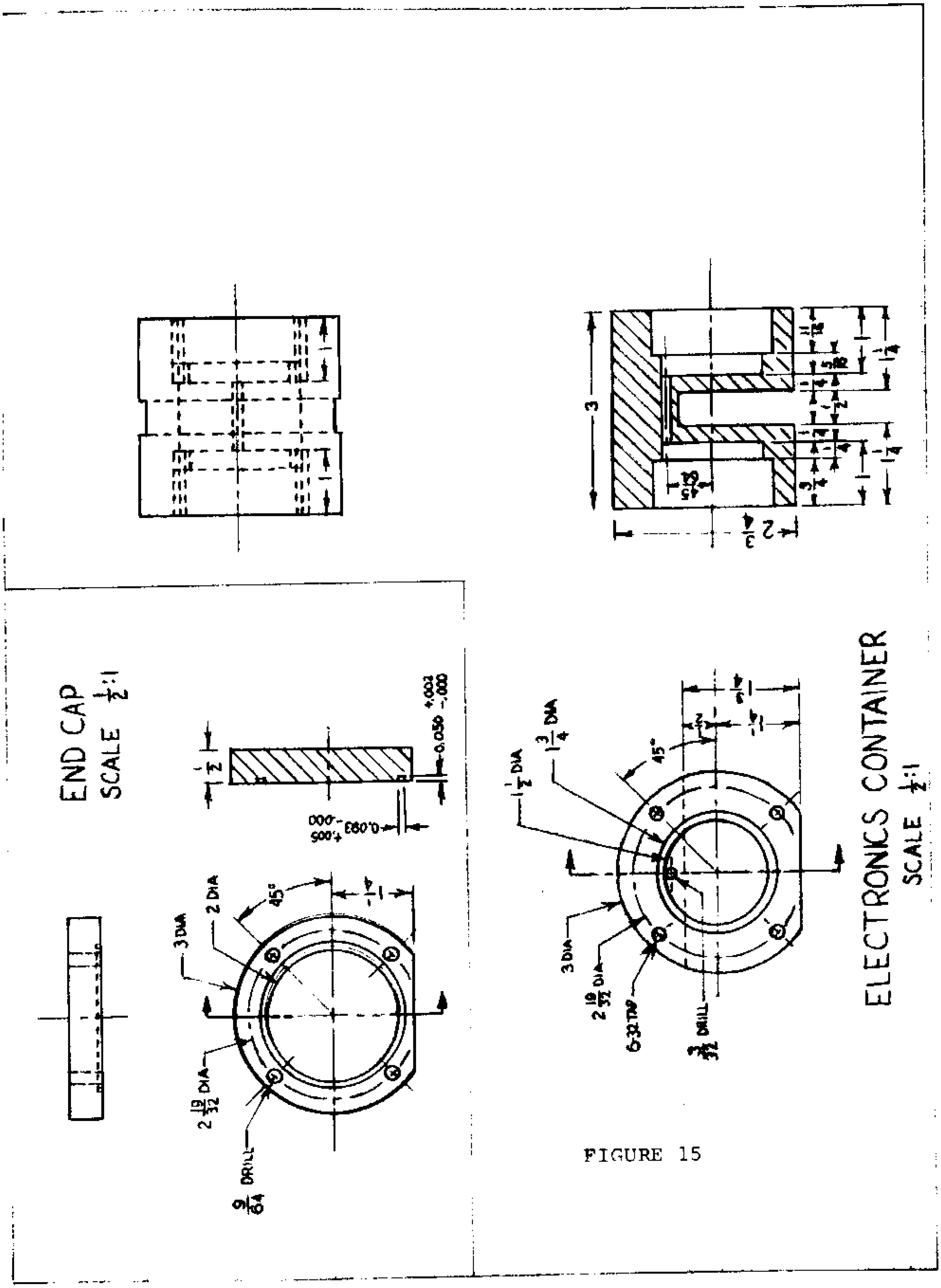

END CAP
SCALE $\frac{1}{2}$:1
3 DIA
2 DIA
45°
$2\frac{19}{32}$ DIA
$\frac{9}{64}$ DRILL
0.093 +.005 -.000
0.050 +.002 -.000
ELECTRONICS CONTAINER
SCALE $\frac{1}{2}$:1
$1\frac{1}{2}$ DIA
$1\frac{3}{4}$ DIA
3 DIA
$2\frac{19}{32}$ DIA
6-32 TAP
$\frac{3}{32}$ DRILL
3
$2\frac{3}{4}$
$1\frac{1}{4}$
.45
.215

FIGURE 15

Propeller Current Meter (con't)

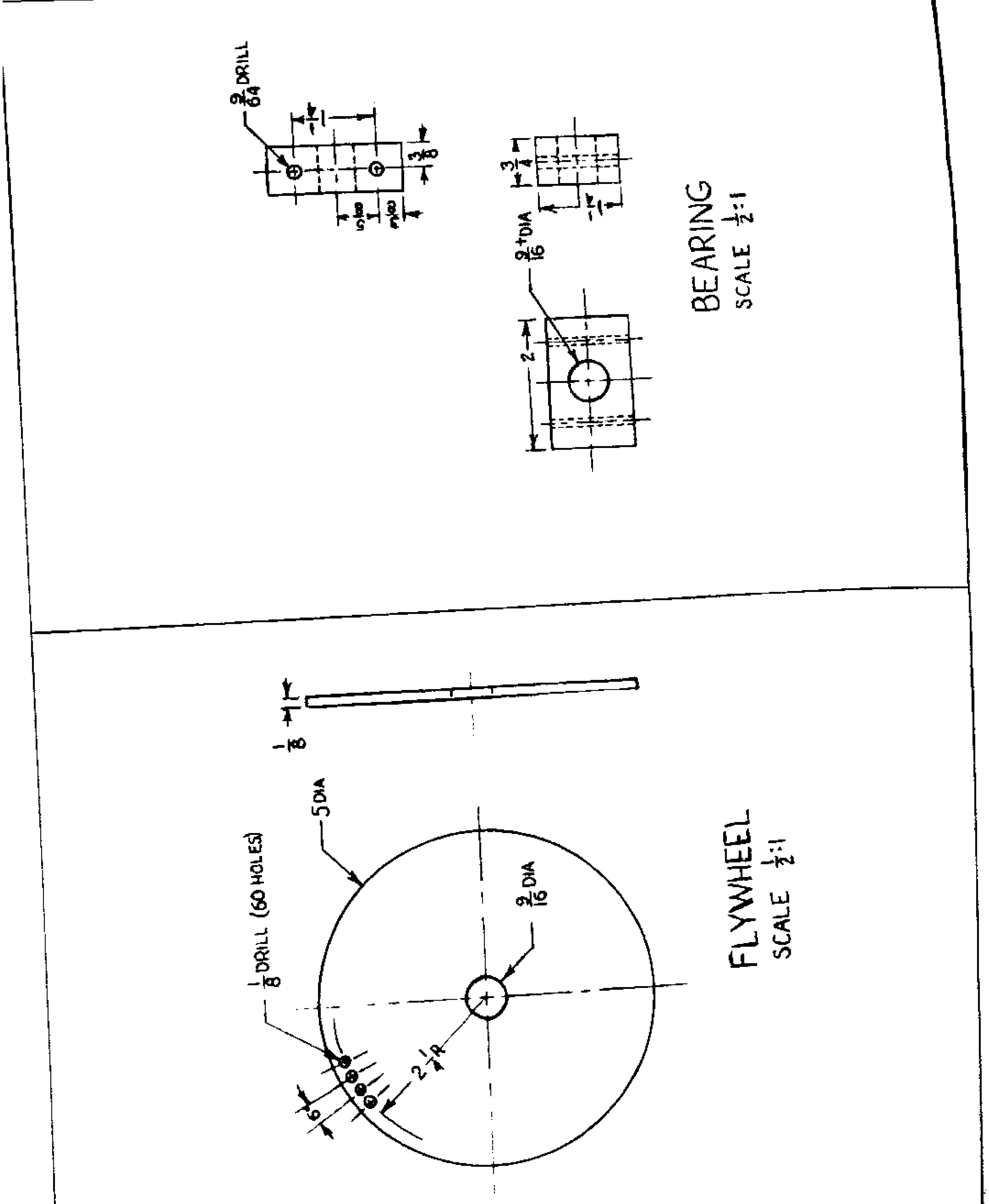


FIGURE 16

Propeller

The propeller was two feet in diameter. It was made of fiberglass, a thin aluminum sheet being used as a mold. See Figure 17.

Mooring System

The shaft and bearing assembly was enclosed by a seven inch diameter cylinder. A rod was put through this cylinder and attached to the diamond shaped harness. 1/4 inch polypropolene line from the bottom was fastened to the lower end of the harness. The line at the top of the harness went to the surface buoy together with the cable. The cylinder rotated freely on the rod and with slight twisting of the mooring lines, allowed the meter to line up with the current regardless of the harness angle due to drag on the instrument and lines. See Figure 18.

FIGURE 17

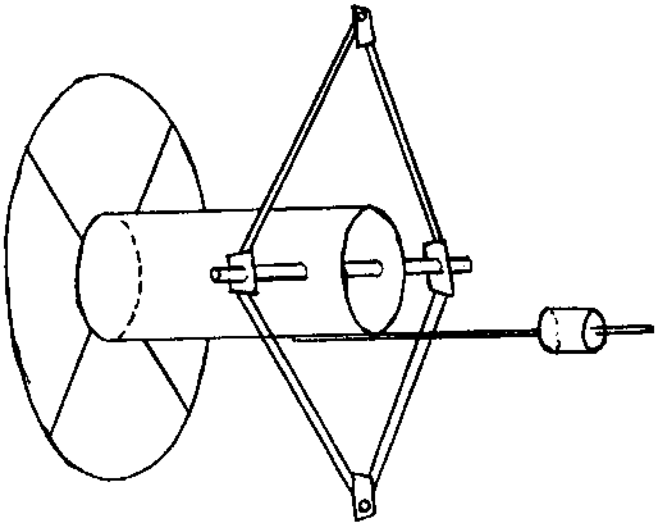


FIGURE 18

To place the meter in position, several steps were required:

1) Two 2 1/2 pound Danforth anchors with concrete blocks were lowered to the bottom directly below the surface buoy already in place.

2) Divers went down to set the anchors on a line parallel to the current direction.

3) The instrument was lowered with the mooring lines and cable attached. The lower line was measured and tied to the anchors by the divers so that the meter was at the desired height above the bottom

4) The divers then tied plastic bottles to the upper mooring line and filled them with air from their scuba tanks. As the instrument was negatively buoyant, this was necessary to keep it at the desired depth

5) The operation was completed after placing the surface electronics inside the buoy and tying off the upper mooring line.

See Figure 19 for details of mooring system.

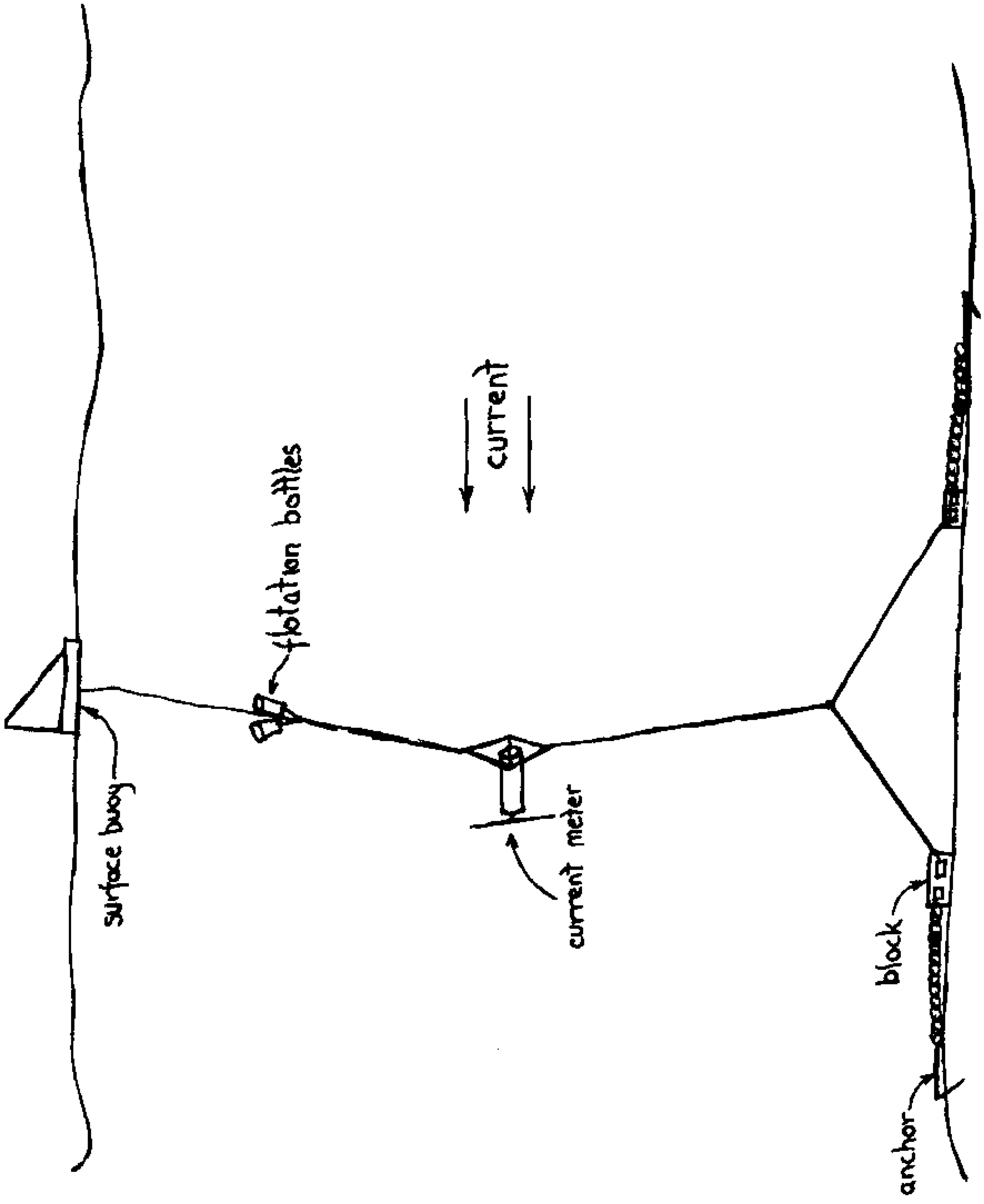

surface buoy
flotation bottles
current
current meter
block
anchor

FIGURE 19

Calibration

The current meter was calibrated at the M.I.T. towing tank. The harness was attached rigidly to the moving carriage and signals recorded to use as reference for later data gathering. The calibration curve is shown in Figure 20.

Suggestions for Improvement

Although the current meter worked reasonably well for a first-try prototype, several changes should be made to improve performance and facilitate handling and the positioning operation.

The shaft and bearing unit was the major weakness of the instrument. It was found to be bulky, unwieldy, and easily subject to damage, and it introduced unnecessary complications and expense. The entire assembly could be simplified by eliminating the shaft, flywheel, and enclosing cylinder. Holes could be drilled directly in the propeller with the light and photocell placed on either side. Needle bearings and Teflon coated ball bearings should be investigated for possible use to reduce friction and obtain higher and less erratic rotational speeds in slight currents.

The propeller should be reduced in size. This, together with the elimination of the shaft and cylinder would greatly reduce weight and drag, and possibly eliminate the need for anchors and divers in the positioning operation.
A simpler one-point mooring might be used instead.

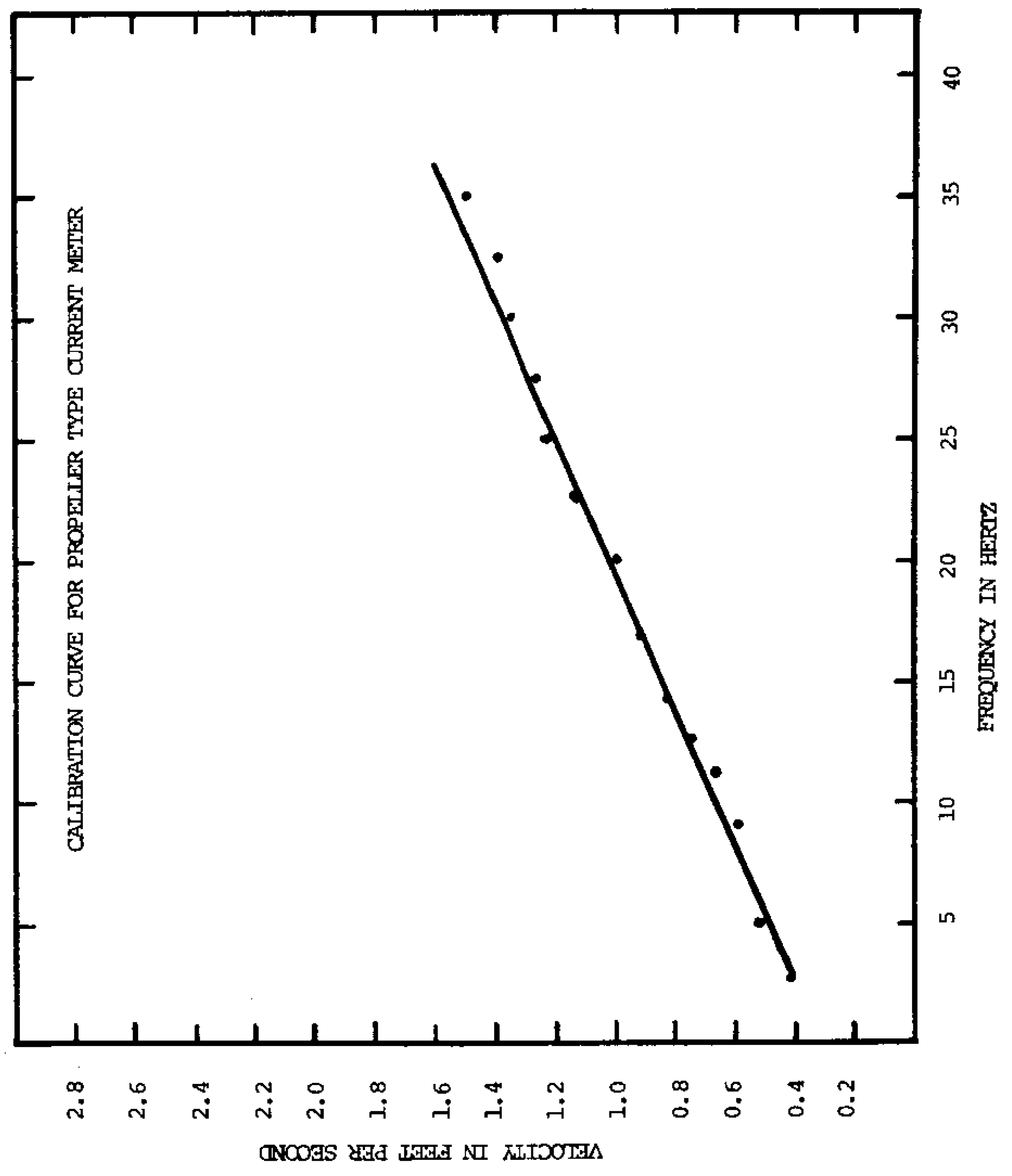

CALIBRATION CURVE FOR PROPELLER TYPE CURRENT METER
FREQUENCY IN HERTZ
5
10
15
20
25
30
35
40
VELOCITY IN FEET PER SECOND
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2

FIGURE 20

Different propeller shapes and, perhaps, a Savonius rotor should be investigated to obtain higher rpm in slow currents. Less expensive electronic components could be used. FET's with the required characteristics are available at a lower cost than the present one.

Once a refined and reliable current speed meter is developed, a direction indicator of some sort might be incorporated. Several possibilities exist which could be developed without undue difficulty.

R. Craig Martin
13.90
September 1971

SAVONIUS ROTOR CURRENT METER

This section will describe a current meter that was designed and built by M.M.A. students, Thomas Eagan and Ernest Decrow.

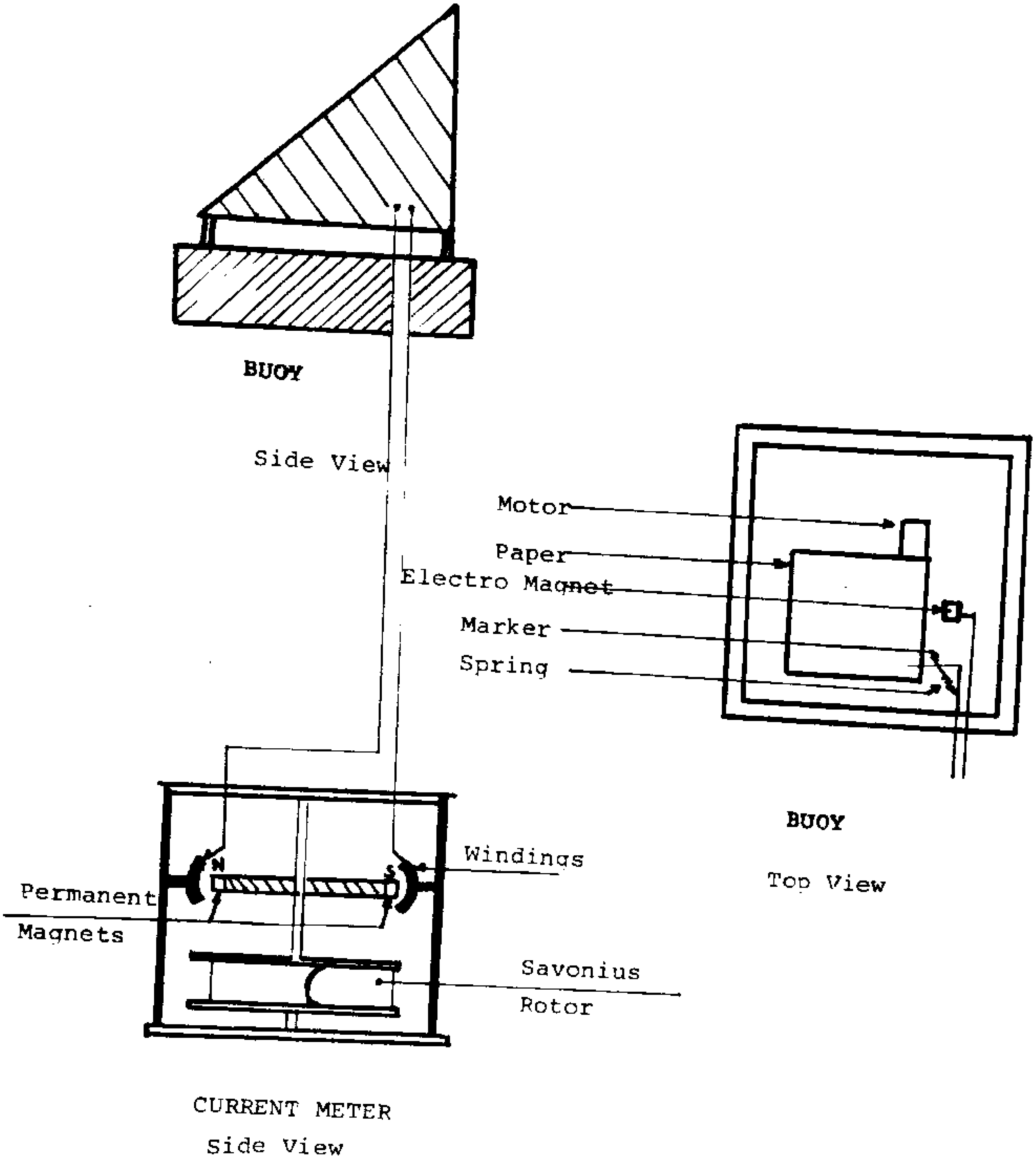
The original design for this meter was a mechanical or electrical device of simple construction, requiring no internal pressurization and no electronic circuits which would be affected by variations in capacitance or inductance.

The original meter was to consist of an impeller which, when rotated, would generate a small EMF and be recorded on a moving graph (see Figure 21). This would be, in effect, a small generator with the electrical pulses recorded on graph paper. This design was replaced by a simpler one because of the time constraints on the project (see Figure 3).

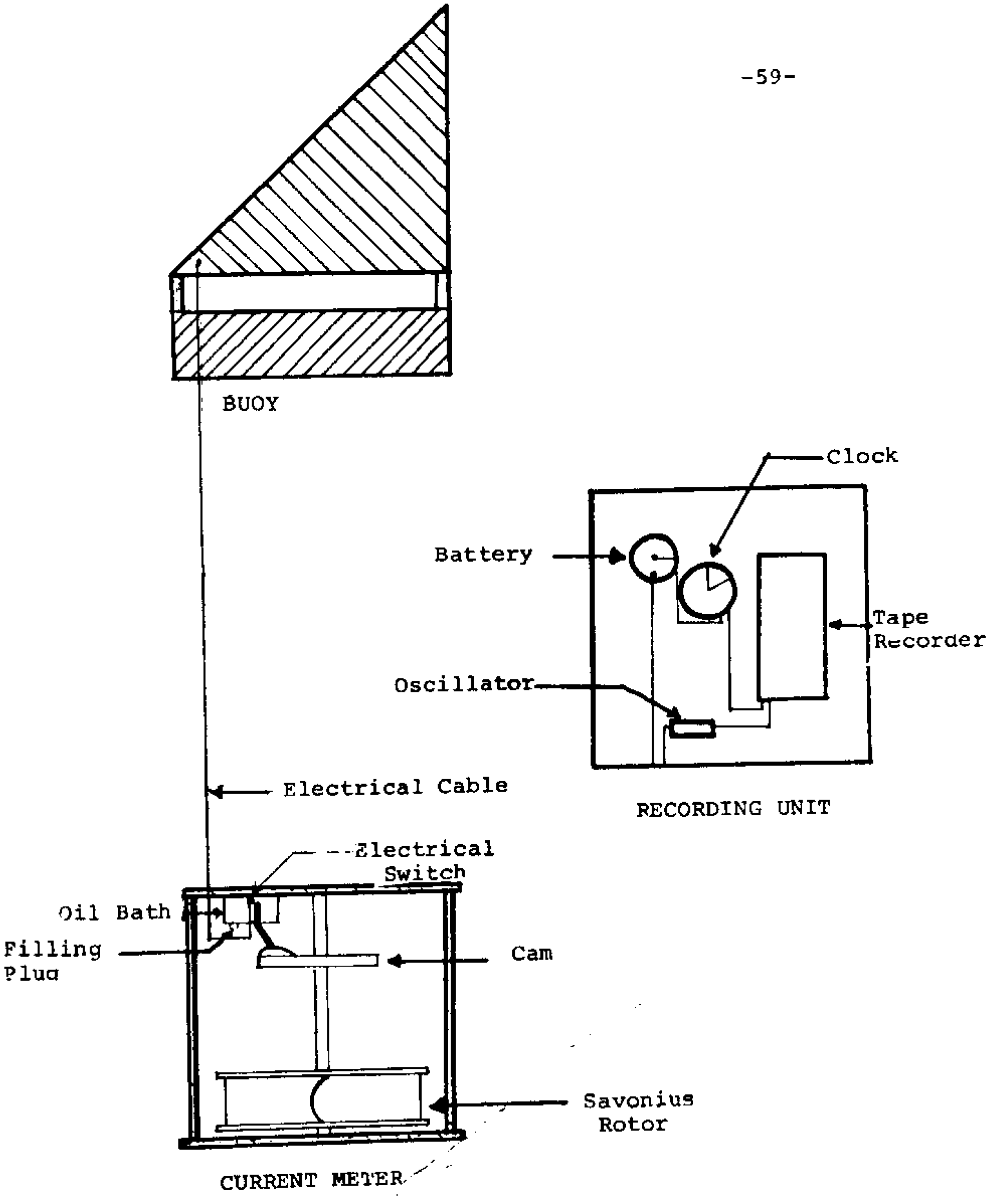
The meter constructed was simply a pressurized switch activated by a cam to complete an oscillator circuit, with oscillations being recorded with a tape recorder. The meter was constructed in two parts - mechanical meter and electrical recorder.

The electrical components were contained within a float at the surface. They consist of a 6 volt battery power supply, oscillator circuit, cassette tape recorder and clock timing relay. The oscillator circuit consisted of a modular form code practice oscillator providing a signal of approximately 450 HZ.

The clock and relay were connected to supply power

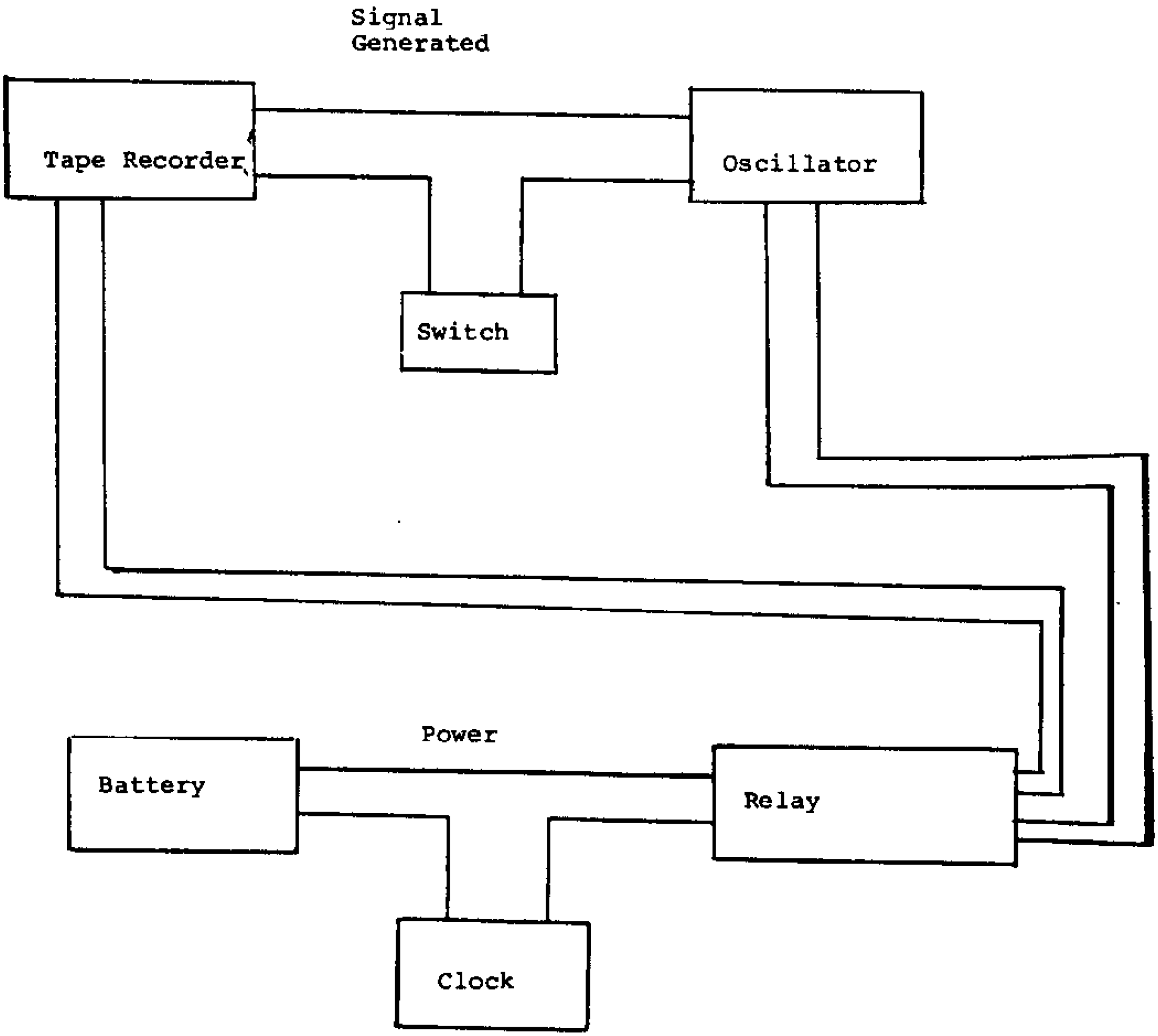


ORIGINAL DESIGN
FIGURE 21



CURRENT METER

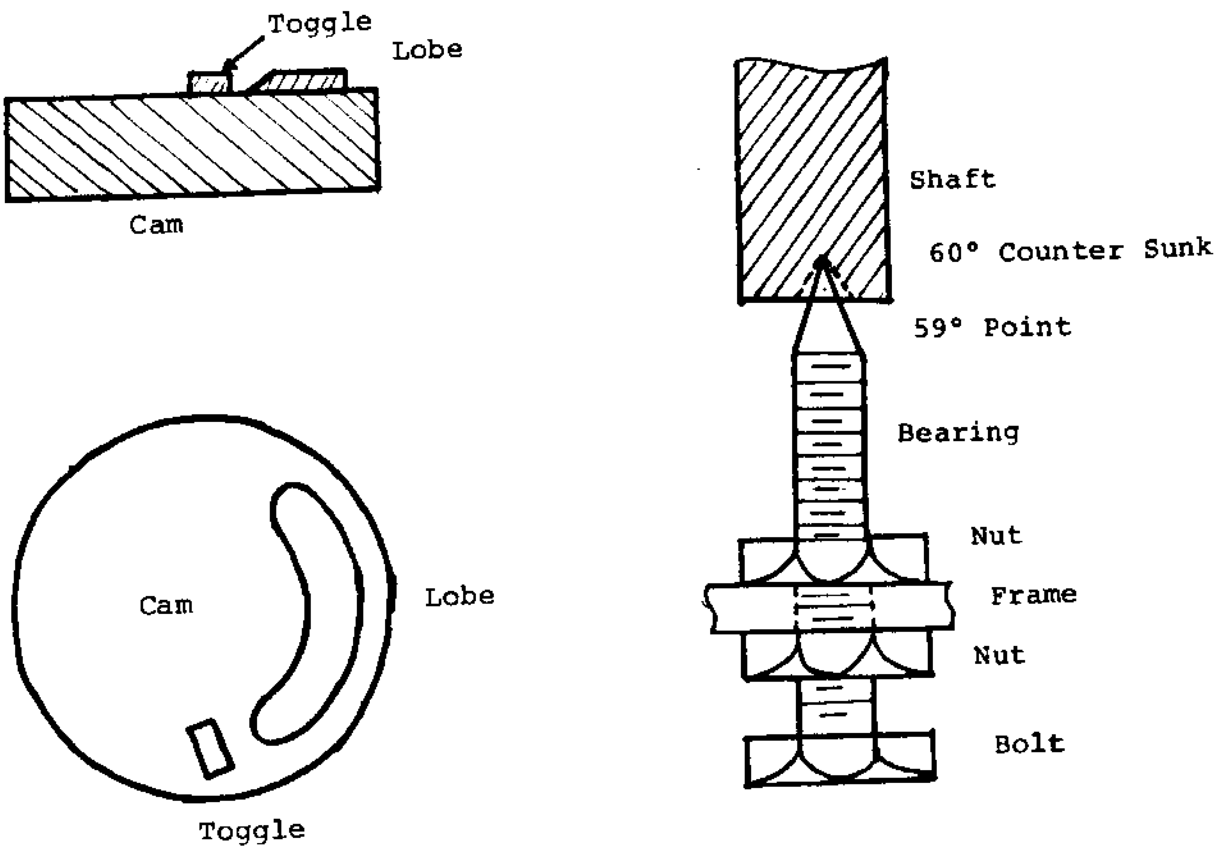
FIGURE 22



BLOCK DIAGRAM OF CIRCUIT

FIGURE 23

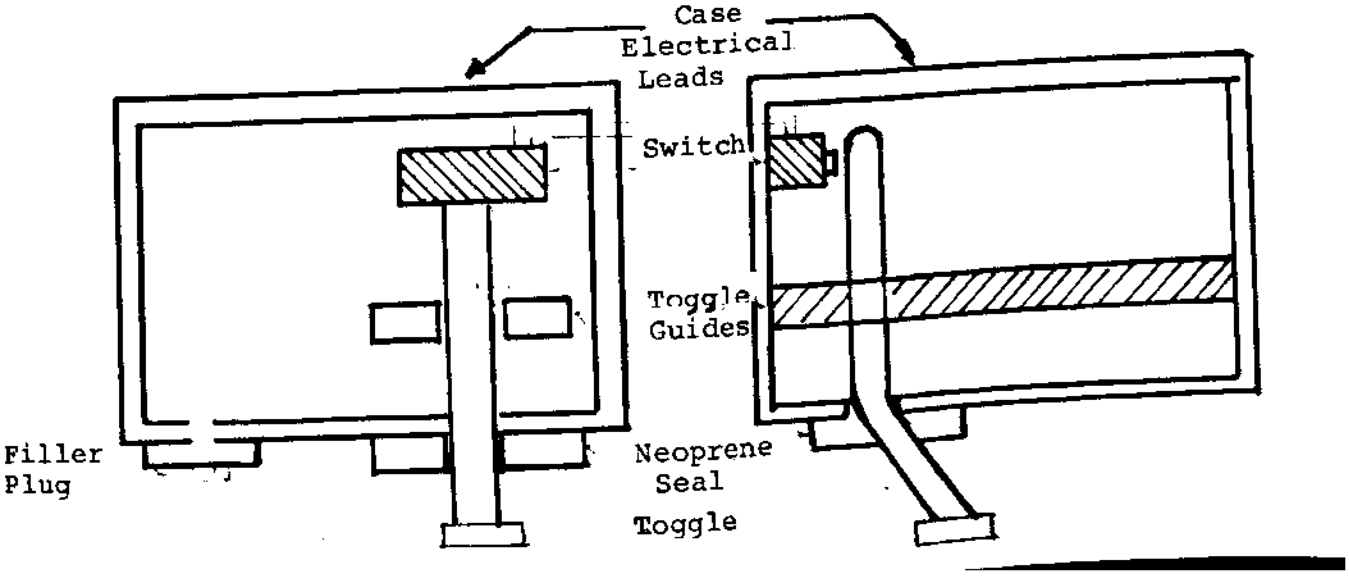
FIGURE 24

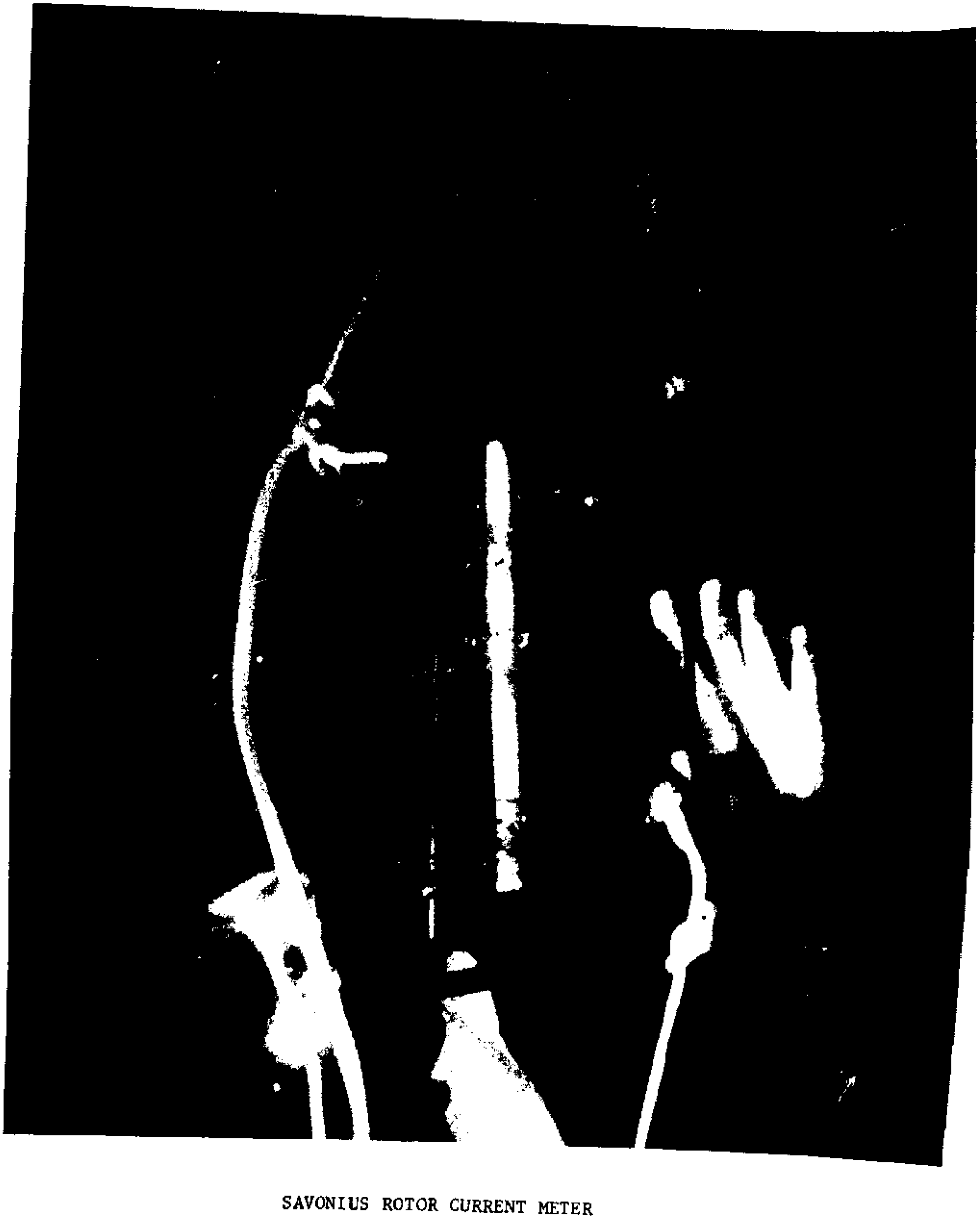


CAM

BEARING

SWITCH CASE





SAVONIUS ROTOR CURRENT METER

FIGURE 25

to the oscillator and recorder at time intervals of 30 seconds every half-hour. This reduced battery use and eliminated the need for constant data recording. The signal from the oscillator was recorded only when the switch located on the meter was closed. A visit to the site is required once every 48 hours to collect data, wind the clock and, if necessary, replace the battery (see Figure 23).

The submerged meter consisted of a steel frame, bearings, rotor, cam and pressurized switch. Support for the rotor and switch was provided by a steel frame with needle bearings on top and bottom. The bearings were machined with 59° points and the nylon shaft was countersunk 60°. Two nuts enable the bearings to be adjusted and locked in place. A small bracket also holds the switch box rigid to the frame (see Figures 24 and 25).

The rotor is constructed from flat plexiglass plates. The rotor is similar to a savonius rotor except it has a single set of vanes instead of two. The rotor is almost neutrally buoyant which reduces friction on the bearings. Connected directly to the rotor by the shaft is a cam which activated the switch toggle.

The switch case is plexiglass with neoprene seals for the toggle and filler plug. The toggle gasket is glued to the switch case and to the toggle providing a flexible seal. Protection from water pressure and leakage is further provided by filling the case with fluid, "Girling" brake

MOORING SYSTEM

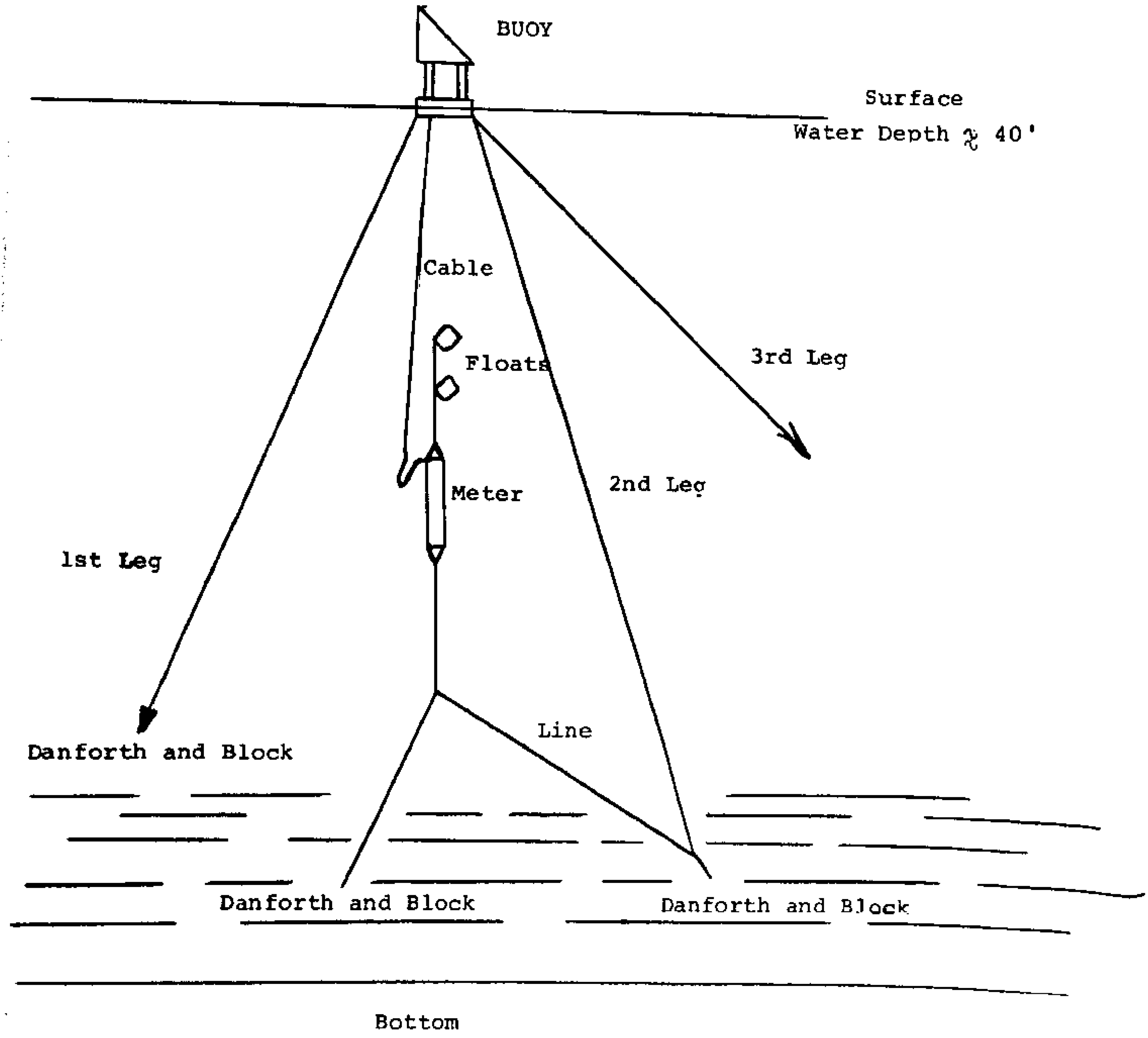


FIGURE 26

fluid in this case. The case should be leak proof at almost any depth. Any difference in expansion between the case and fluid should be compensated for by the toggle seal. If leakage should occur in the case, the water will collect at the bottom of the case and will not come in contact with the switch.

The mooring system used was a three point mooring to the buoy with a two point mooring to the meter.

The three legs each consisted of identical parts, a small 2 1/2 lb Danforth anchor, a cement block attached with five feet of chain, and a 1/4" line to the buoy.

The mooring system for the meter was made up of one leg from the buoy mooring and the second leg from a Danforth anchor and chain. A line was tied between the meter and the buoy anchor (see Figure 26). Two one gallon milk bottles were used as underwater buoys to provide an upward force on the meter. A short length of line was used at each end of the meter to provide a bridle for securing lines.

The following is a list of improvements and problems of the meter. The rotor had a tendency to stall at slow current velocities. The stalling occurred because the rotor was made with only one set of vanes. Adding a second set of vanes to the present rotor would eliminate the stalling.

When the meter was first submerged, a steady signal was recorded. Insufficient waterproofing of the electrical connection between the switch wires and hydraphone cable caused the short. The connection was made water tight using epoxy glue.

The meter frame corroded rapidly in the sea water. However, the steel frame was unpainted. Painting the frame with primer and anti-fouling paint would prevent corrosion and fouling.

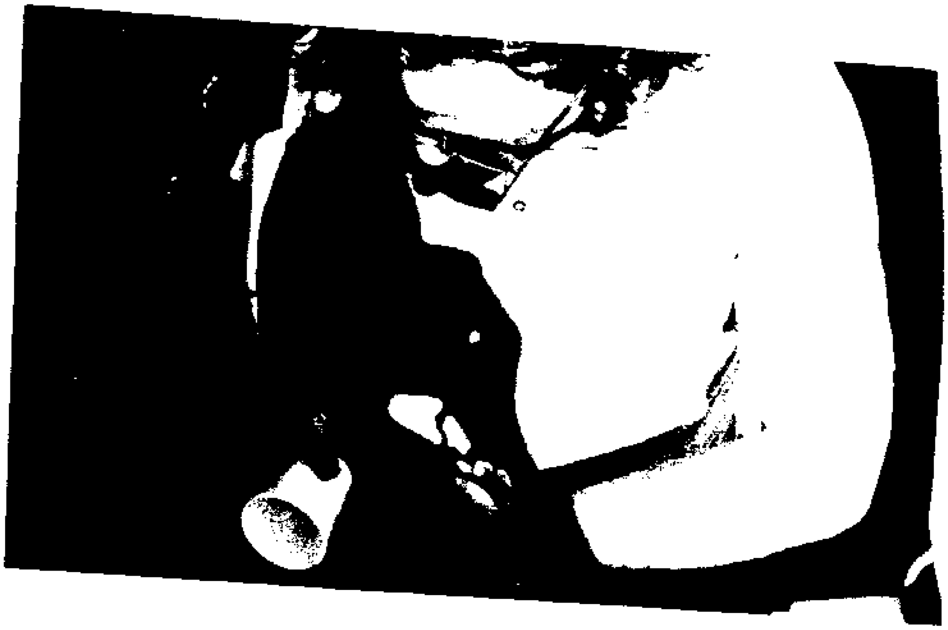
Although the switch case remained water tight, a better toggle seal could be constructed. A double compression seal would compress and seal the toggle gasket circumference. The toggle could be made in two pieces with a pair of mating thickness and flanges to make a seal. The outer seal could also be made by a two piece fitting with mating threads. The internal threads would be made of plastic and glued to the switch casing. An internal ring would compress and seal the gasket.

Thomas Egan
David DeCrow
Maine Maritime Academy
September 1971

STYROFOAM CUPS

In this project it was necessary to have a measuring device that would determine the average top to bottom current velocity at any one point in time and location. By accumulating data along a line from one shore to another, it is an easy matter to determine the time dependent volume flow rate for any given channel and hence, the flushing action present there. This information is important for setting the best schedule to reopen Goose Pond, if such is to be done

In all our designs we strive for simplicity, reliability, ease of construction and/or preparation, and accuracy. This device is no exception. The heart of the device is a 6 oz. styrofoam cup, the same used for take-out orders in many restaurants. The shape of the cup ensures that no matter what orientation it has relative to the local current, it will have sufficient drag so that it can be assumed that the cups acts as a particle of fluid. From here it is a logical step to weight the cup so it sinks to the bottom, and then upon impact releases the weight in order for the cup to return to the surface. Thus only one person on the surface is required to operate this device. With the range, direction, and time for the round trip, the average current can be determined.



CUP
ADJUSTMENT

THE DROP

CUP
SINKING
NEXT CUP
READY
FOR
DROP

FIGURE 27

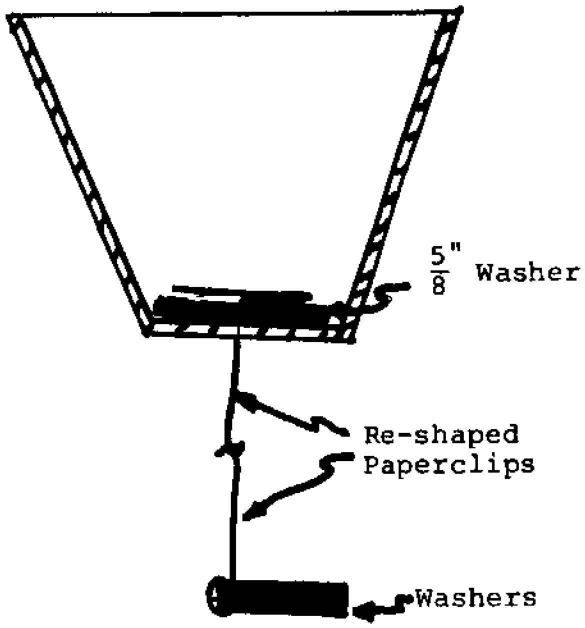


FIGURE 28

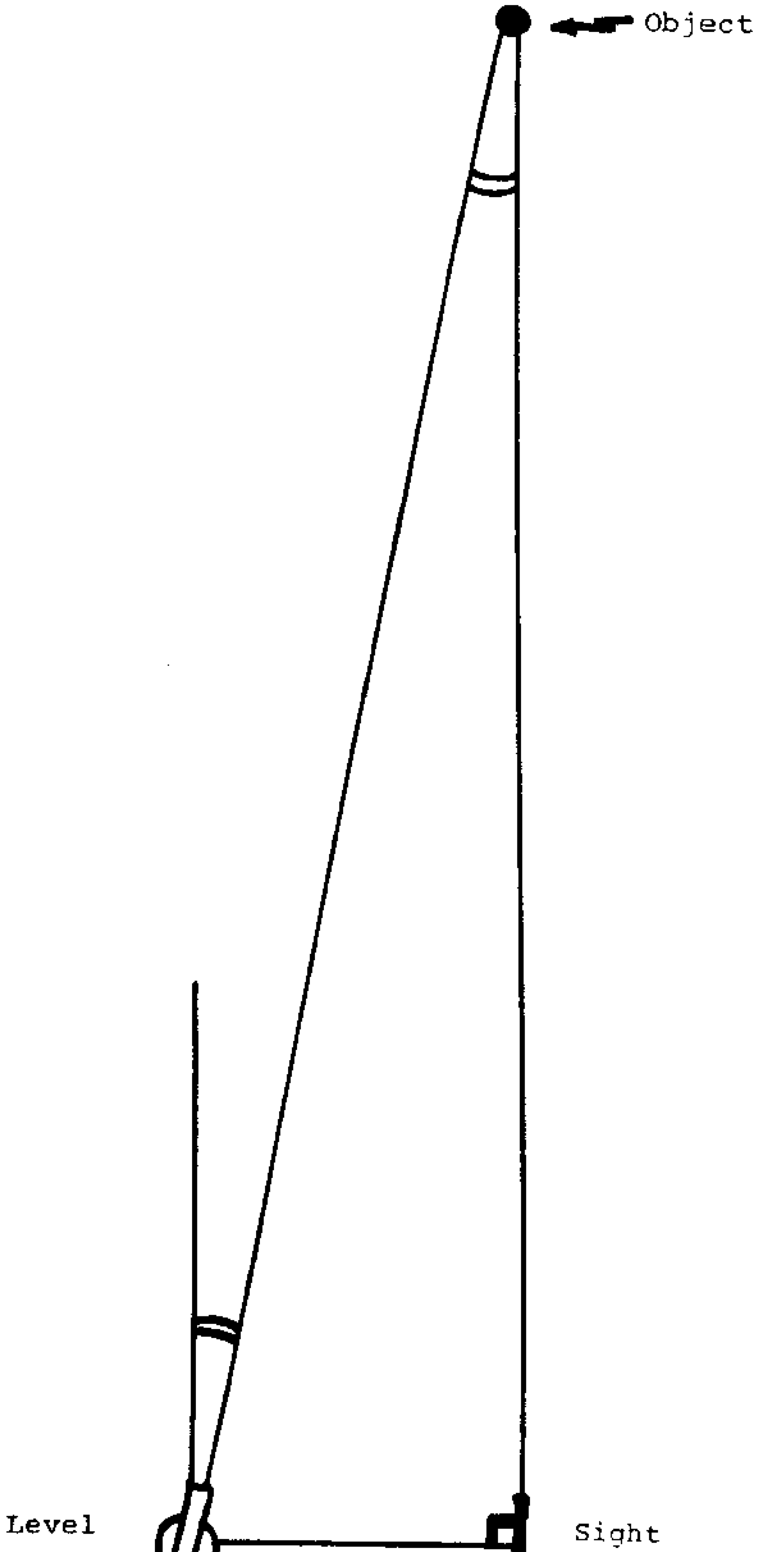


FIGURE 29

For weight we used a combination of 1/2" and 5/8" galvanized washers attached to each cup with two paper clips reshaped into hooks (see Figure 28).

The first design for a range finder was based on a camera range finder (see Figure 29). A sight, a level, and the object make a triangle. With two angles and one side known (the separation of the level and sight) the range is calculable. With a 3' separation, the accuracy at 200' is 1%. One major problem with this range finder is that we had to use it from a boat, and because of the small field of vision and depth of focus, it was impractical to use.

The second design was a small, light line with floats tied on at 10' intervals. The surface current draws the lime out, and the cup always returned close enough to the line to determine the range accurately.

Time and direction are easily determined with a stop watch and hand bearing compass, or by using landmarks.

This author cannot think of any better way to determine average top to bottom current than the present system.

Robert Powers
13.90
September, 1971

RECORDING CURRENT DIRECTION METER

The overall design parameters for the direction meter were to be the same as for the other instruments:

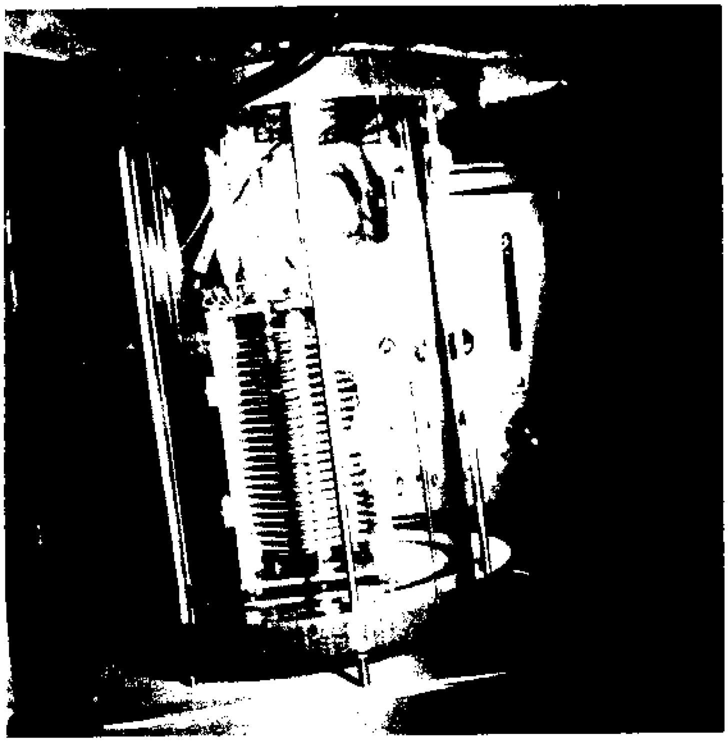
1. A device which could be serviced through a surface float.
2. An electrical circuit which would have an audio output utilizing a variable capacitor for input.
3. A surface float to provide power and housing for a magnetic recorder and a time keying system.
4. Be operable in currents up to 3 knots and depths up to 70 feet.

The specific functional requirements were determined to be:

1. A directional reference system.
2. A mooring system to allow station keeping anywhere from just below the surface to the bottom in up to 70 feet.
3. An input system to the variable capacitor.
4. A housing for the capacitor and electronics.

For the directional reference system, we rejected the idea of having an internal compass which we felt would require that one of the capacitor plates be attached to a compass. We felt we could gain the reference system through a rotationally stable 3-point mooring.

This brought us to consideration of the mooring. For design purposes we considered an instrument platform with three five-foot legs in the horizontal plane. We estimated that the assembly with the instrument container would have a negative buoyancy of 25 lbs. To maintain a taut mooring which would be necessary for station keeping we then had to



CALIBRATION
OF
CURRENT
DIRECTION
METER

TRASH BAG
FISH NET
FLOATATION
DEVICE

FIGURE 30

add additional buoyancy above the platform. Experience with styrofoam flotation had shown it to be less than satisfactory at depth, so we developed a variable-buoyancy float which would be inflated with the exhaust from a scuba regulator. This was easily done by using waterproof balloon (see Figure 30). We wanted to use 1/4 inch polypropylene for moorings which limited us to 1,000 lbs tensile strength which with a safety factor of 6, means 183 lbs. tensile or for 3/16 inch we could go to 283 lbs. tensile.

or for 3/16 inch we could go to 283 lbs tensile.

The input for the instrument package was chosen to be a vane which would turn the capacitor shaft. This would be a weak point in the system and the design should allow for this consideration. A through-hull fitting with "O" ring seals is needed for the shaft.

The housing was constructed of plexiglass in cylindrical form with end caps and "O" ring seals. The two end caps would be held on by six axial rods going through the overhanging edge caps. The transparency of the housing would also aid in the detection of leaks. A through-hull fitting with a quick disconnect capability was provided to allow pressure equalization with a modified scuba regulator while emplacing the device.

Calculations

1. Determine tilt of buoyancy float due to current drag:

Assume Spherical $C_D \sim 1.0$

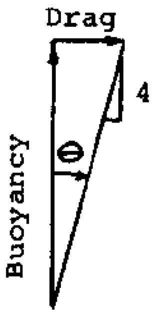
$DRAG = C_D 1/2 P V^2 A = 25A$ where $A = \pi R^2$

Buoyancy Force $= PV = 64(\frac{4}{3})\ \pi R^3 = 264R^3$

The tilt of the buoy will be the tilt of the device.

Restricting ourselves to $TAN\theta = 1/4$

or:



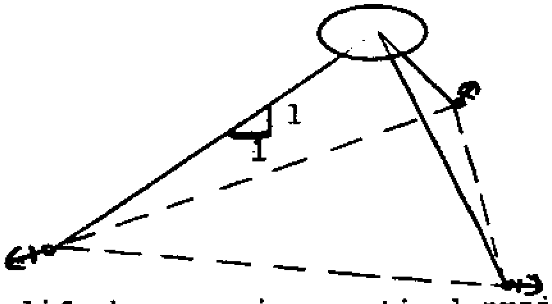
$\frac{78.5R^2}{264R^3} = 1/4$ $R = \frac{4x78.5}{264} = 1.2$

$B = 264(1.2)^3 = 264(1.728) = 458$ lbs.

minimum diameter for float = 2.4 ft.

2. Determine deformation of cables in mooring system

Assume slope of 45°



Simplify by assuming vertical projection of 50' & $C_D = 1.0$ concentrated at midpoint.

$Drag = C_p 1/2 P V^2 A = 25 \times 50 \times 1/4 \times 1/12 = 25$ lb minimum line tension = $\frac{458}{3} \times \sqrt{2} = 216$ lb

deviation is ∿ 1/(span of 16) which is acceptable and non-limiting.

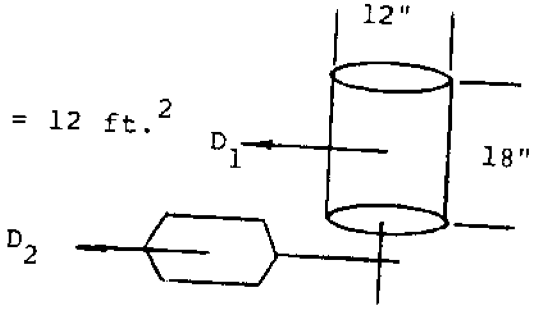
Actual case would involve buoyant catenary which would be less effected. Thus, our approximation is conservative and acceptable for station keeping.

3. Terminal moorings - Assume mud bottoms. Using Danforth lightweight anchors with a five foot chain and a concrete construction block.

From Section (2) minimum tension would be 216 lb.
A 10 lb Danforth is rated @ 500 lbs.
" 5 lb " " " " 250 lbs.

4. Instrument Assembly

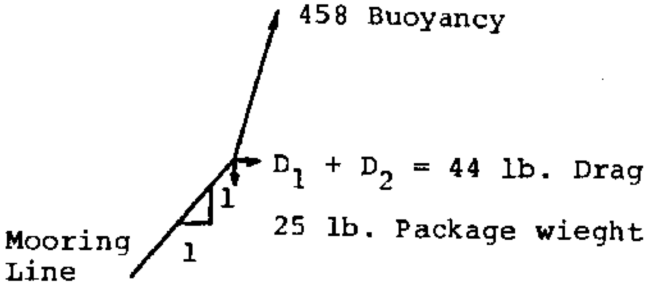
Vane Area = 2 x 6 ft.^{2} = 12 ft.^{2}



$D_1 = C_D 1/2\ \rho V^2 A = 25A = 37.5$ lbs

$D_2 = C_D 1/2\ \rho V^2 A = 2 \times 10^{-3} \times 25 \times 12 = 6$ lbs.

Is it possible for this drag to collapse the 3 point system?



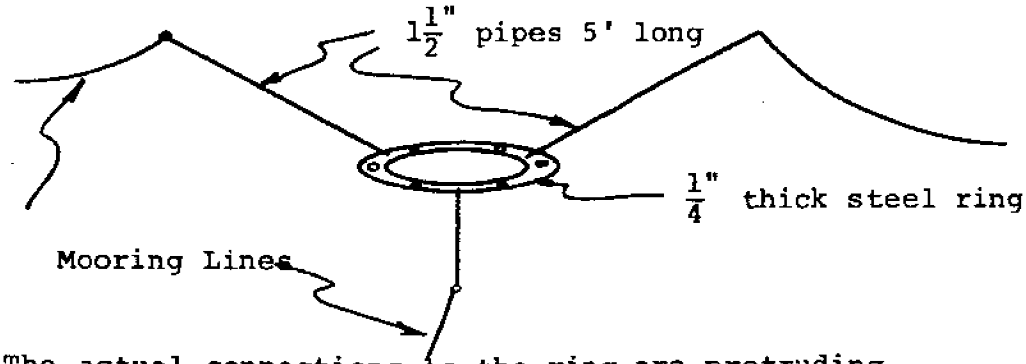
Summation of drag forces would have to be

$$\frac{458}{\sqrt{2}} = 324 \text{ lbs before collapse}$$

Therefore, no danger of collapse with that configuration.

5. Instrument Platform

Should be as simple as possible and still mate mooring to instrument package.



The actual connections to the ring are protruding nipples with cotter pins to allow disassembly for moving.

The juxtaposition of the assembly and the platform was chosen for several reasons:

1) Having the valve below does not require major axial forces on the capacitor shaft and results in the through-hull fitting, which is the most probable leak point, being on the bottom of the package.
2) The center of buoyancy is above C.G.
3) The two drag forces partially cancel each other for rotation in the vertical plane about the platform.

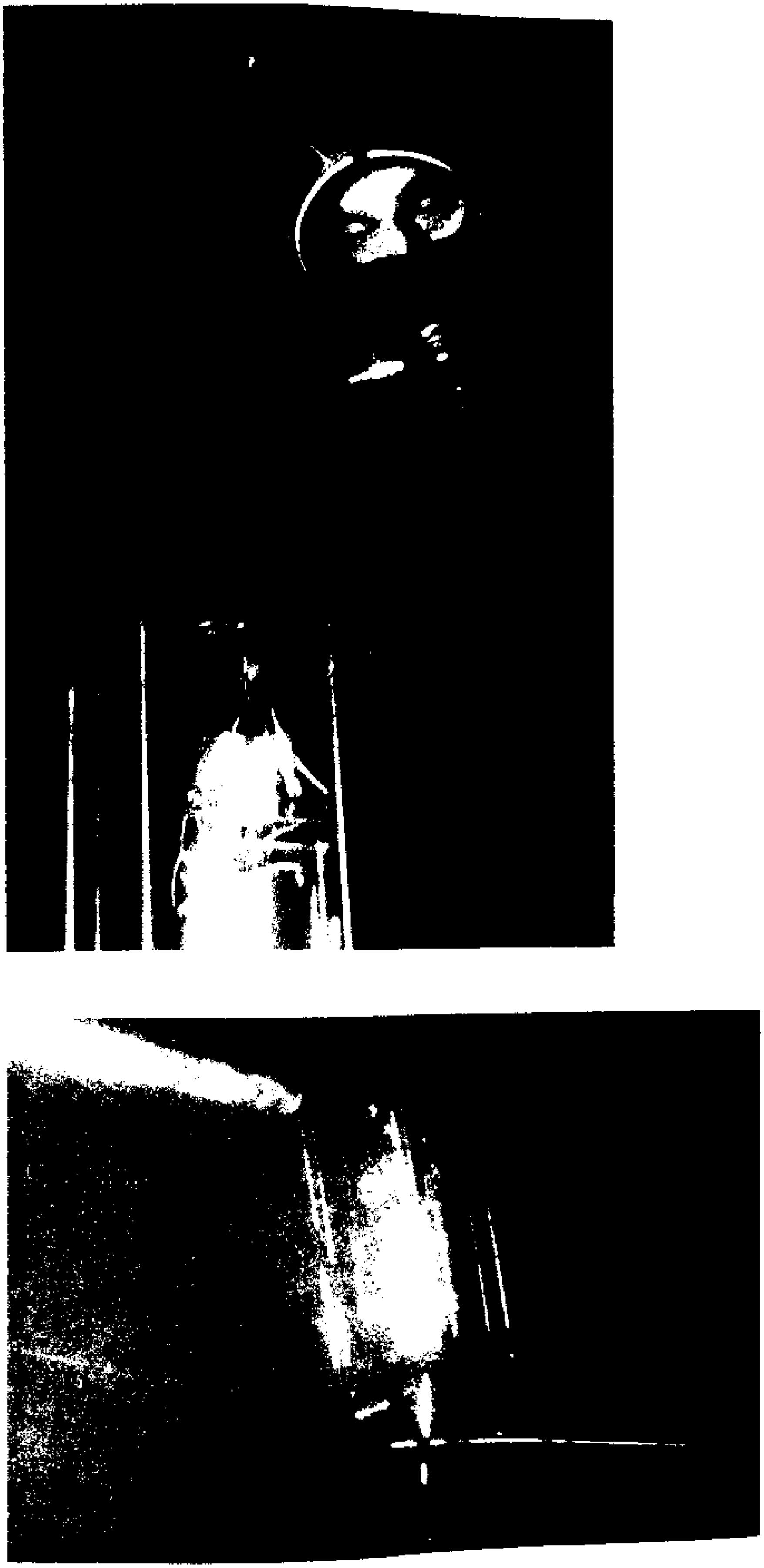
4) The problem of impeding the rotation of the vane with the buoyancy float moorings was avoided.

6. Electronics

A circuit with two oscillators and the variable capacitor was powered by ±6 volts D.C. and had an output flow 20 HZ to 600 HZ which was pretuned prior to sealing the housing. A wire hydrophone cable provided leads for ground, +6 volts, -6 volts, and signal out. The lead was run from the housing through one of the platform pipes to the surface float.

7. Capacitor Vane

Since the "O" ring seal around the capacitor shaft made rotation somewhat hard, we made a vane of the dimensions shown below and used syntatic foam



CURRENT
DIRECTION
METER

FIGURE 31

filler in all cavities to avoid depth-dependent buoyancy. To insure that we woudl have only an axial force at the capacitor shaft a movable keel was included. This allows adjustment of the vane to the point where the net buoyancy of the vane is assumed by axial loading on the shaft and the vane is in stable horizontal equilibrium (see Figure 31.)

Critique of Performance

1. Currents on location were in vicinity of knot and mooring was assembled using 1/4 inch polypropylene and 2 1/2 lb Danforth anchors (125 lbs holding rated in mud). We experienced no problems with the anchors and used these concurrently as moorings forthe surface buoys. The polypropylene line was difficult to use for knots, and for reliability all joining was done by splicing with 50% more tucks than would be required with natural fiber rope.

2. The device was extremely difficult to put on station or adjust due to the numerour steps which required divers The rotationally stable mooring simplified the instrument design, but greatly increased diving time foı putting on station, steps required were:

a) Putting in 3-point mooring with surface buoy.

b) Lowering platform by electronic cable with scuba rig attached to pressure compensate.

c) Pressure compensating.

d) Placing the 3 mooring lines to the buoy anchors.

e) Bringing down deflated flotation buoy and attaching.

f) Inflating buoy to achieve taunt system and adjusting.

g) Dropping vertical weighted line from platform to bottom to insure accurate position in water column.

h) Placing recorder and power package in surface buoy.

i) Attaching vane and adjusting to zero moment condition.

j) Recording reference direction of housing.

3. The electronic circuit we used was subject to considerable drift due to water vapor. Even with the sealed housing we still found this to be a problem. Calibration did not insure being able to rely on data for interpretation.

4. The area we were working in, experienced a 10 foot tidal range. With the variable buoyancy float above the platform, it was necessary to inflate and test at high tide to insure that at minimum volume there was sufficient buoyancy. As the tide ebbed the volume of the balloon would increase to a maximum at low water.

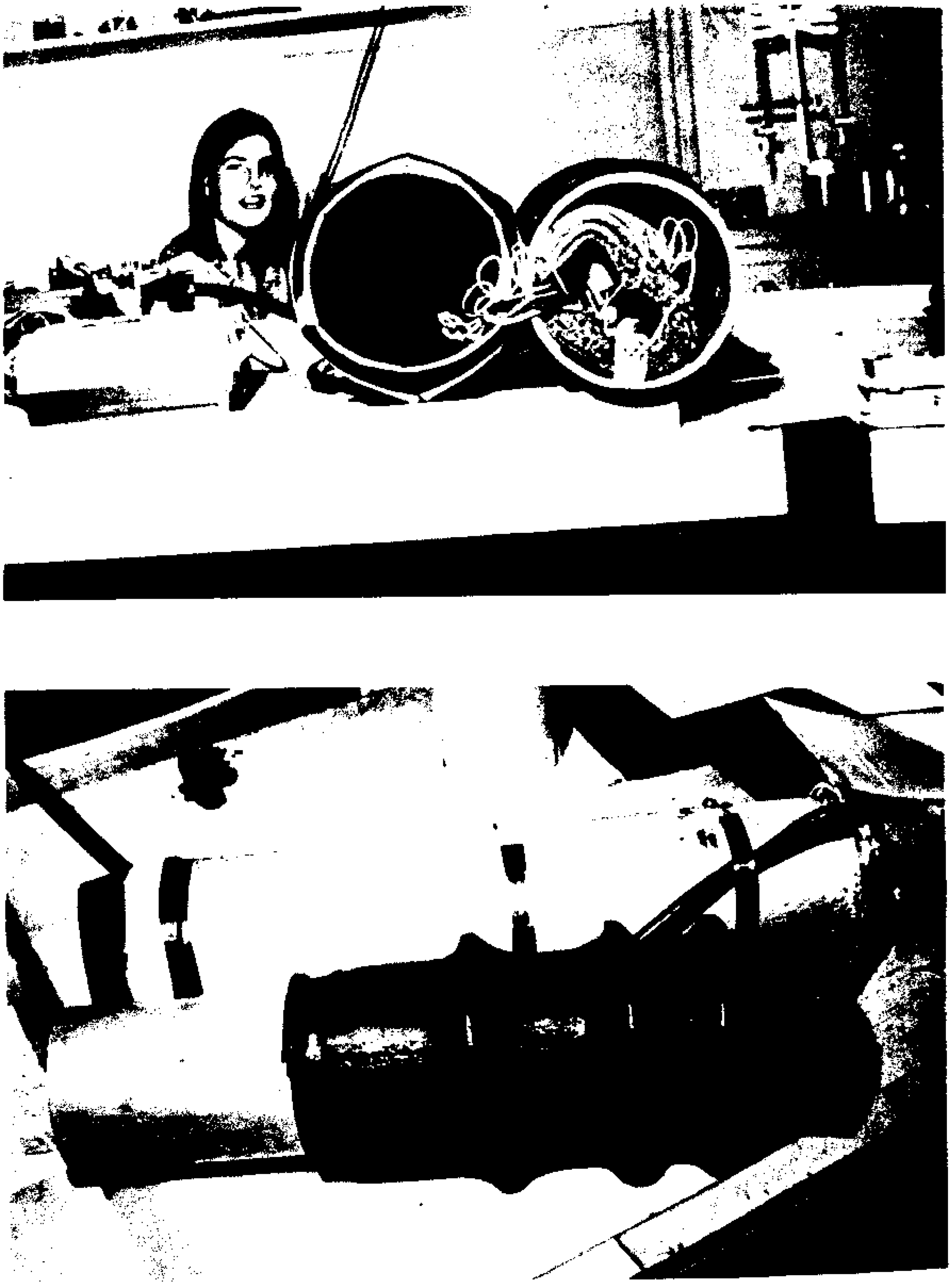
TIDAL HEIGHT INDICATOR

The experimenters studying the Penobscot Bay wanted to know the change in tidal height as a function of time. Since a purportedly reliable capacitor circuit was immediately available which would produce different frequencies using a variable capacitor, it was decided to design the tidal height indicator around the specifications of the oscillating circuit. This designer decided upon the use of a cylindrical capacitor which would have a constant mass of air sealed inside it and would then change capacitance as the volume of the air increased and decreased with changes in hydrostatic pressure related to tidal height. The frequencies produced could be tape recorded at the desired time intervals by using a clock mechanism to operate the recorder.

Basically, the circuit is a capacitance transducer whi amplifies a beat frequency produced from two oscillators - one of constant value and the other tuned by a variable capacitor (in the range of zero to 200 pico farads). The electronics was powered by a plus and minus six volt d.c. source; it was originally designed for use as a wave height gauge using an insulated steering cable as one capacitor plate, and the seawater as the other. (See Appendix II in this section for more details on the electronic circuitry.)

Calculations of capacitance for various gap widths and pipe radii were made using the formula for cylindrical capacitors:

$$\text{Capacitance} = \frac{2\pi\varepsilon_o L}{\text{Ln}(b/a)}$$



VARIABLE CAPACITANCE PRESSURE GAGE

FIGURE 32

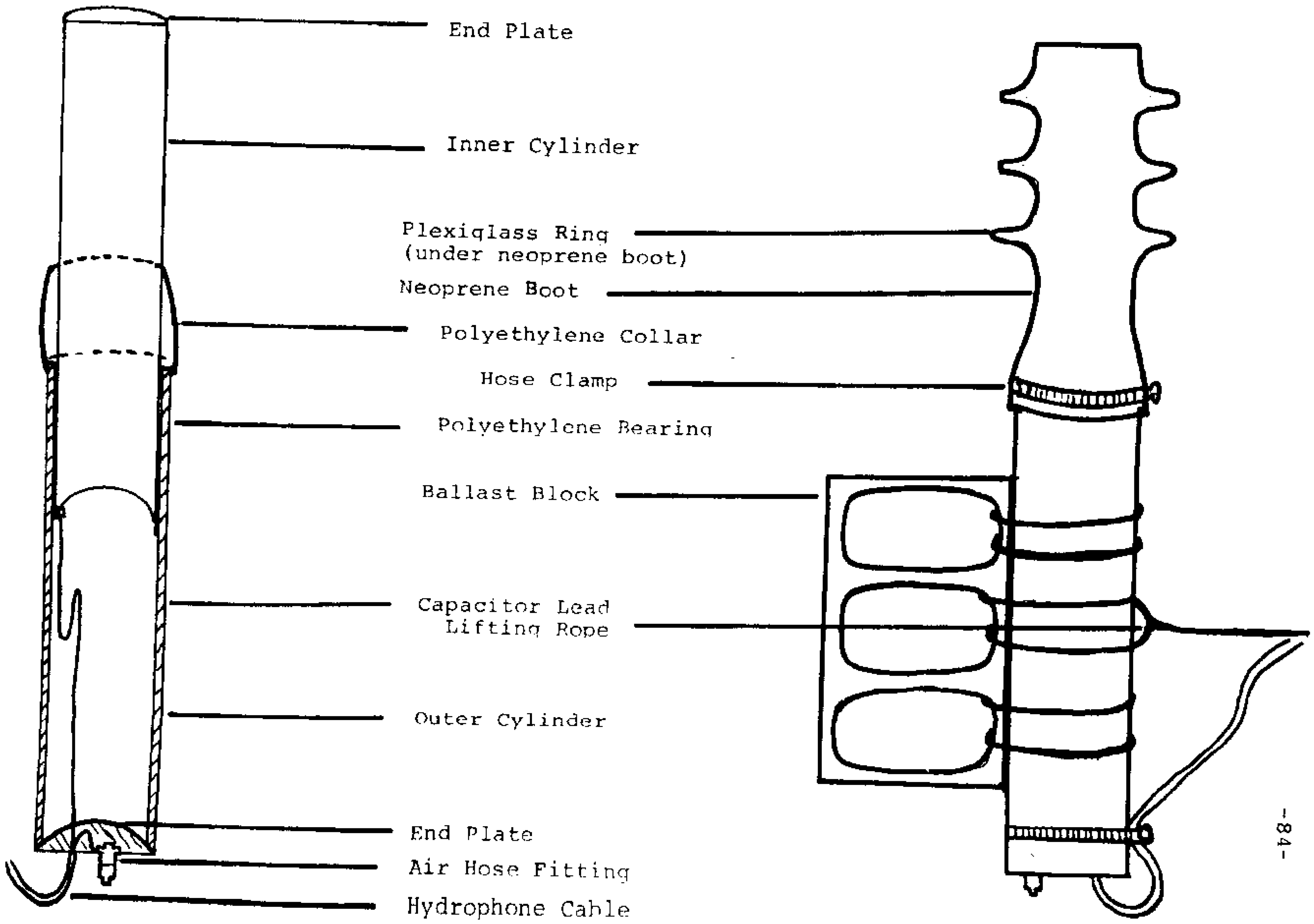

End Plate
Inner Cylinder
Plexiglass Ring (under neoprene boot)
Neoprene Boot
Polyethylene Collar
Hose Clamp
Polyethylene Bearing
Ballast Block
Capacitor Lead Lifting Rope
Outer Cylinder
End Plate
Air Hose Fitting
Hydrophone Cable

FIGURE 33

where L is the length of capacitor plate overlap; b is the inside radius of the outerpipe; and a is the outside radius of the inner pipe. ε_o is the permittivity constant the value of which is 8.9 x 10^{-12} coulomb^2/NT-M^2. These calculations indicated that the outer pipe should have an inside diameter of 4 1/4" and that the outside diameter of the inner pipe should be 4". The gap width then is one-eighth inch. (See Appendix I for data on different pipe diameters, gap widths, and their respective values of capacitance). Since aluminum pipe is more corrosion resistant than ordinary steel (and much less expensive than stainless steel), it was decided to use aluminum pipes. In this case, the pipe sizes required were available only in 6061 T6 aluminum tubing.

The construction and deployment of the tidal height indicator was quite straightforward. One end of each pipe was sealed by welding an aluminum plate over it. A quick disconnect air hose fitting was then installed in the end plate of the larger pipe (the ground plate of the capacitor) for use in adjusting the relative pipe positions when the unit was submerged. An insulating cylinder of 1/16" polyethylene was then fitted inside the larger pipe to keep the smaller pipe from touching the other and shorting the electronics. The smaller diameter pipe (both pipes are 18 inches long) was fitted inside the polyethylene cylinder and a conical collar of polyethylene was attached to the end of the larger pipe extending about 4 inches over the smaller pipe to keep the neoprene insulating boot from squeezing into the gap between the pipes during compression. This 12 inch neoprene boot, shaped like a cup, was given accordion-like characteristics by using three 5 inch diameter lucite (plexiglass) rings so that the inner pipe should not be stuck in a compressed mode by folding of the neoprene. The boot was clamped by a stainless steel hose clamp to the larger pipe. Electronic connections to the surface were made by connecting 2 wires of a 4 wire hydrophone cable to the two capacitor plates; the entrance holes for these wires were sealed with epoxy. A concrete block was tied to the capacitor with sisal rope for ballast. The air pressurization hose was connected and the rig was lowered into the water by divers at the end of the dock.

Initialization of the capacitor extension rig was done and the rig was then lowered to the bottom in water approximately 25 feet deep at the mean tide height. On the surface the electronics, including two six volt dry cells, a battery operated tape recorder and the timing clock were connected. This surface gear was stowed in a wooden box at the dock. A tape was placed into the tape recorder and the water tests were made. The clock mechanism would operate the tape recorder for approximately 30 seconds every half-hour.

From the beginning, the electronics of the system never worked correctly. The frequency range of the circuit is from zero to 800 Hertz; higher frequencies are mostly filtered out. The circuit was tuned so that the range of frequencies was correct. The system was then calibrated at high tide by suspending the underwater portion at depths differing by one foot within the expected tidal range. This process was performed while the tape recorder was turned on and thus, a calibration tape was produced. However, by the following day, the frequencies were not in the same range. Several successive calibrations were made, always producing the same ambiguous results. An analysis of the problem yielded two probable areas of difficulty. The man who engineered the circuit (Professor J. Milgram) explained that the circuit would drift for reasons of which he was not certain, possibly due to humidity and/or temperature changes. Professor Milgram also noted that there seemed to be problems involving the grounding of the underwater capacitor plate (the larger pipe) - problems which may have been solved by placing the electronic circuitry inside of the underwater capacitor instead of at the surface. His second suggestion was heeded, but the frequency range still varied daily and retuning of the circuit now involved removing the rig from the water, disassembling it, readjusting the oscillators of the circuit, assembling the capacitor again (insuring water tightness), initialization and deployment by a team of divers and finally another recalibration. Therefore, it was concluded that the electronics could be placed at the surface with little loss of accuracy, facilitating easier circuit adjustments. What was needed was a circuit which would maintain a stable frequency range.

Several aspects of the mechanical properties of the system should be mentioned. The first of these is that the system was mechanically quite good: it did not leak and the inner sliding pipe would move freely within a six inch range. Secondly, and perhaps one of the few drawbacks of the system, the underwater capacitor needs to have air forced into it as it descends for emplacement - a task best done by a scuba diving team. This is a drawback in that divers are necessary for deployment of the equipment. The initialization could not be done on the surface because the necessary inflation represents too large a volume of air and too much stress would be placed upon the neoprene boot.

Melvin Wolpert
13.90
September 1971

Appendix I

Table #1 - Pipe Radii and Capacitance Data.

Appendix II

Circuit diagram and Description of the Electronic Circuitry used in the Tidal Height Indicator.

APPENDIX I

$$\text{Cylindrical Capacitance} = \frac{2\pi\varepsilon_o L}{\mathrm{Ln}(b/s)} = \frac{(56 \times 10^{-12})(L)}{\mathrm{Ln}(b/a)}$$

a = radius to the outside of the inner cylinder

b = radius to the inside of the outer cylinder

$\varepsilon_o = 8.9 \times 10^{-12}$ coul^2/ntm^2 (permittivity const.)

L = length of capacitor plate overlap

a(meters)	b(meters)	g p(inches)	Outside diameter of inner cylinder(in.) (200a)-(2.54)	Capacitance(farads/meter)
.0068	.01	1/8	.535	145 x 10^{-12} farads
.0084	.01	1/16	.66	322 "
.0168	.02	1/8	1.32	322 "
.0184	.02	1/16	1.45	649 "
.0268	.03	1/8	2.11	496 "
.0284	.03	1/16	2.24	1045 "
.0292	.03	1/32	2.30	2030 "
.0368	.04	1/8	2.89	679 "
.0384	.04	1/16	3.02	1395
.0392	.04	1/32	3.10	2860 "
.0468	.05	1/8	3.68	840 "
.0484	.05	1/16	3.81	1780 "
.0492	.05	1/32	3.86	3520 "
.0496	.05	1/64	3.90	6250 "

FIGURE 34

APPENDIX II

Description

Beat Frequency Oscillator for Tide Gauge

1. Purpose

The modal WG-2 wave gauge is a capacitance transducer designed to provide an output frequency directly proportional to wave height. The wave gauge is capable of providing a 400 HZ deviation for senser lengths of between 18 inches and 45 feet.

2. Electrical Specifications

Output	15 volt square wave
Temperature range	10-4° centigrade
Linearity	better than .5% of deviation
Deviation	400 HZ for selected ranges
Stability	less than 2 HZ/C
Senser lengths	18 Inches 5, 15, and 45 feet

3. Power

The modal WG-2 is designed to operate from a plus and minus 15 volt power supply.

4. Output

The output is 15 volt square wave with a deviation of of ±200 HZ from a mean of 500 HZ.

5. Connections

Power is furnished to the instrument via pins 2 and 3

pin 3	+15 volts DC
pin 2	-15 volts DC
pin 7	instrument ground*
pin 4	signal output
pin 8	senser connection (steering cable)

---

*A good ground connection must be furnished from the ocean to the instrument ground.

THEORY OF OPERATION

The modal WG-2 wave gauge consists of two heterodyned oscillators, the output of which is filtered to recover the beat frequency. The beat frequency is now filtered, amplified, shaped and squared into a 15 volt square wave.

Oscillators

TR1 and TR2 are conventional colpitts oscillators designed for a center frequency of 31 KC. The only difference begin that in oscillator-2 provisions have been made to frequency modulate the oscillator by varying the tank circuit capacitance with a senser unit.

Changing Range

Either by changing the LC ratio of the tank circuit or the location of the senser unit in relation to the tank capacitors it is possible to obrain a 400 HZ deviation for any senser length between 18 inches and 45 feet.

Mixing

Mixing of the two oscillators is accomplished by the load resistors R4 and R'4 and CR1. Changing the effective load on oscillator-2 by varying R'4 will determine the width of the output pulse.

Filtering and Squaring

The filter is a low pass operational amplifier with cut-off at 1,000 HZ. Additional filtering is accomplished with R7 and C4. TR3 and TR4 provide the pulse shaping and squaring networks respectively.

FIGURE 1

WAVE GAUGE

Model WG-2

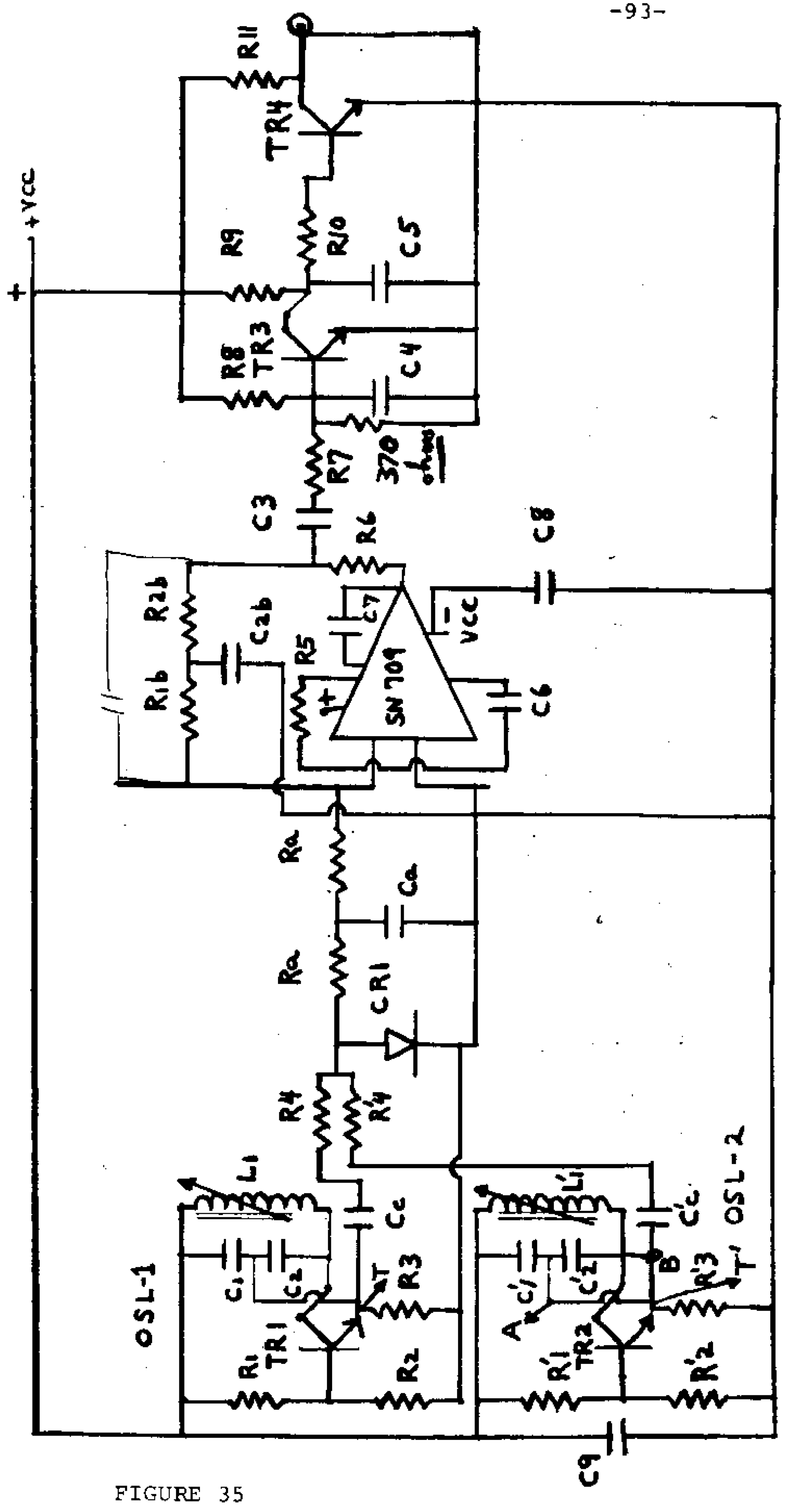


FIGURE 35

CALIBRATION

The initial calibration of the instrument may be made with the unit out of the case, after a 15 minute warmup period for stabilization.

Procedure

1. Measure the frequency of oscillator-1 at test point T. (Junction of emitter resistor R3 and coupling capacitor Cc). Set this frequency to 31KC ± 10 HZ by tuning the slug in coil L1 with a noninductive screw-driver.

2. Measure the frequency of oscillator-2 at test point T'1. (Junction of R'3 and C'c). Set this frequency to 30.3KC ± 10 HZ by tuning the slug in coil L'1.

3. Measure the frequency of the output at pin 4, it should be 700 HZ ± 20 HZ, if not recheck oscillators 1-2. A low impedence probe will load the oscillator and cause erroneous readings.

The instrument is now ready for field calibration.

Field Calibration

The instrument should be calibrated in the case and on site whenever possible. Final calibration consists of setting the output frequency to 500 HZ for a mean water height equal to 1/2 the senser length.

1. The senser should be immersed in water to the selected mean water tank on the senser. The output is now set to 500 HZ ± 10 HZ by tuning the slug in coil L'1.*

---

*The output frequency should be directly proportional to the height of the waves.

MATERIAL LIST

Ward Lenard RN60C
Metal Film Resistor

R1, R'1, R2, R's	8250
R3, R'3	3920

Carbon resistors 1/2 watt

R4	5.1K
R'4	4.7K
Ra	680
R1b	91K
R2b	51K
R5	1.5K 1/4 watt
R6	51 1/4 watt
R7,R10	100
R8	6.2K
R9	30K
R-11	2K

TR1-TR2	2N335
TR3-TR4	2N706
OP1	SN709
CR1	1N67

L1 L'1	Miller #9059	1.3-3mH
	Miller #9060	3-10mH

General Electric
Lectrofilm B 65F
Capacitors
C1-C'1, C2, C's, Fig. 2,3,4,5

Ca	.33MF
C1b	.0015
C2b	.0033MF
C5	.068MF

Mallory
Tantalum CS13 Capacitors

C3	33MF
C4	3.3MF
C8	100MF
C9	100MF

CC	.01MF disk
C6	.005MF disk
C7	200PF disk

Connector
Cinch 250-10-30-170

PHOTOGRAPHIC EQUIPMENT AND TECHNIQUES

The equipment we had consisted of the Nikonos II camera with a 35 mm lens, a strobe, and three filters. We also had the use of several private cameras.

The strobe was loaned to us by Dr. Edgerton. The filters consisted of a circular polarizing filter system, a red filter and a green filter. The camera and strobe were completely waterproof.

Both the polarizing and red filters were used to reduce backscatter which was predominately green, while the green filter was used to increase contrast when photographing above the surface.

The film used was high speed Ecktachrome for color and Tri-X pan for black and white. Most photography was done in color because black and white could be easily made from color, but color could not be made from black and white. High speed film was chosen because many situations existed where light would be dim and grain size was generally not very critical or limiting.

The filters were not used very much. Difficulty of attachment or lack of light were the reasons why the polarized filter system was not used. (The filters which were held in place with tape tended to come off in the water). Since fewer pictures were taken with black and white film than had been anticipated, both the red and the green filters saw little use.

The strobe was only used for about 5% of the surface pictures, but was indispensible for the underwater shots because of contrast and color considerations as well as absolute light levels.

Not enough use of the private cameras was made. They were generally more versatile than the Nikonos, and should have been a major source of surface pictures. However, due to poor organization, the opportunity to use them was not completely exploited.

No exposure meter was provided for the Nikonos. As a result, most pictures had to be shot in groups of three on different estimated exposures to be sure of getting a good picture and the result was probably better than a waterproofed light meter would have given. The meter if used, should be waterproof, as it is difficult to estimate exposures underwater.

Next time, I would suggest that there be two photographers designated. One should be for surface photography and should have his own camera with an interchangeable lens system. His ownership of this gear should be a primary consideration in his appointment. The other should be for underwater photography and given the Nikonos with the 28 mm lens as opposed to the 35 mm lens. The 35 mm lens was a great handicap in turbid water, but must be used if it is the only camera lens, since the 28 mm lens will not focus properly above water. The polarizing filtering system was worth the effort to develop, as several pictures appeared that would have been improved greatly by it. The only suggestion is that a better attachment system be provided.

The photographer should have been encouraged to practice more before the trip, especially underwater shots with black and white film. Someone who is dry in the boat should be shown how to change the film in the Nikonos II, so that the diver need not get out of the water and dry off to change it. Also, 36 exposure film rolls mean fewer changes. Finally, picture taking underwater should not be delegated to only one day, as this introduces the unnecessary risk of all the pictures being spoiled, rather than just one day's worth.

Robert Biles
13.90
September 1971

EQUIPMENT FOR WATER QUALITY ANALYSIS

Three different pieces of equipment were used to gather data and water samples, by those students in the project who were involved in pollution study of the Penobscot River area. The Secchi disk was a 20 centimeter diameter circular disk, painted white, and attached to a twenty foot chain which was marked each foot for measurements. Its purpose was to measure visibility and it would be lowered down into the water until it could no longer be seen. Then it would be lowered a few feet more and then pulled up until it could be seen again. The average of these two depths would be taken as the visibility.

Second was the bathythermograph (BT), whose purpose was to give a complete record of the water temperatures from the surface to the bottom below the particular station. Shaped like a rocket, it had temperature sensitive coils on one end beneath the fins and an internal pressure sensitive chamber, similar to the mechanism of an aneroid barometer. As it was lowered, it etched on a gold plated slide a graph of pressure versus temperature, which could be read and interpreted for thermoclines on a special, calibrated slide reader (see Figure 36).

Third was the Nansen bottle which was used for gathering water samples at various depths. Attached to a heavy line at two places, it was lowered as a long open tube

WATER
SAMPLING
WITH
NANSEN BOTTLE

BATHYTHERMOGRAPH
SLIDE

SALINITY
TESTS ON
WATER SAMPLES

FIGURE 36

which let water freely pass through it allowing no air to be trapped in the sample (particularly important for testing the oxygen levels in the water). At the desired depth, a messenger weight was dropped along the line which would strike the top attachment point of the Nansen bottle to the line, and mechanically release it. This caused the Nansen bottle to arc 180°, pivoting around the one remaining attachment point, and as a result mechanically sealing off the tube at both ends with the sample enclosed ready to be hauled up and transferred to sample bottles.

Richard Katz
13.90
September 1971

DATA ANALYSIS IN THE GOOSE POND REGION

A fundamental decision was made upon arrival in Castine to concentrate current and water sampling work in the region shown on the chart (see Appendix A) between Holbrook Island and Cape Rosier in the vicinity of Goose Pond. This area is henceforth, referred to as "Goose Cove" in the absence of an official name on the chart.

This decision was made due to an immediate major pollution problem that was of concern to local residents and the local fishing industry. There is at present a copper strip mine in operation which is using Goose Pond for disposal of ore wastes. They have dammed the entrance from Goose Pond into Goose Cove. At the end of this year the mine will be shut down and the dam removed allowing open communication between the waste in the Pond and the Goose Cove-Penobscot Bay seawater. Our efforts were, therefore, aimed at obtaining current data in the Goose Cove and adjacent Penobscot Bay region to gain an insight into the eventual path of mine pollutants. Extensive water sampling was done in the Goose Cove area for comparison after the dam is opened.

Current data was obtained using the styrofoam cup technique and the propeller - photocell current meter both of which are described elsewhere in this report.

The first set of current data was taken at 2 stations across the channel from the entrance to Goose Pond to Holbrook Island (see Figure 37). These measurements were taken with styrofoam cups so that an accurate appraisal of average current over the depth could be made. The results indicate a larger volume flowing north during the flood tide than flows south during the ebb. In other words, the incoming tide flows through this channel from Penobscot Bay and sweeps the Goose Cove water into the Bagaduce River estuary in the vicinity of Castine. The outgoing tide tends to bypass this channel and flow out the river to Penobscot Bay.

The next station for current measurements was between Nautilus Island and Holbrook Island at the north end of the cove. Measurements here were taken with the propeller-photocell current meter over a week. Since measurements were made only at one depth at one station they serve only as an indication of current velocities and not of total flow. Since measurements were made over a week at various tide ranges, all velocities are normalized on a mean tidal range basis assuming velocity to be proportional to range. The data points were faired by harmonic analysis using a fundamental period and five harmonics. The results for this station are shown in Figure 38.

There is another entrance to this cove between Nautilus Island and the mainland but the depth is shallow and exposed at low water. Flood currents of about 1 ft./sec. flow through this channel starting about 2 hours after low tide. This flow carries some Goose Cove water into Castine Harbor, but the depth is so small the total volume is assumed slight in comparison to the main channel.

On the basis of this information, it may be concluded that if the wastes from Goose Pond are opened to the tidal water, the incoming tide will carry this waste into the Bagaduce River at Castine Harbor. The weaker outgoing tide will carry waste into the Penobscot Bay in the Cape Rosier area. Further styrofoam cup measurements in the Bagaduce River off Castine (see Figure 39) indicate that currents in the river are lower than the 2 knot figures often heard. Maximum currents of less than one knot were observed. The flushing action of the river is, therefore, considerably less than might be expected.

Water quality measurements were made in conjunction with the current data to give a basis for comparison after the mine is closed down.* Salinity and temperature data was gathered to aid in understanding stratification of the flow noticed while making current measurements. Particular attention was given to concentration and dispersion of heavy metal ions (primarily copper and zinc) introduced from surface runoff from the mine area. Little is known at present of the effects of these ions on marine fauna. However, the deleterious effect of minute concentrations of these ions on several commercially important species in Maine has been documented by Dow (see Peference 5 on Page 120).

Analysis of temperature and salinity data at different tide stages indicates a stratification, which is frequently very sharp, between deep sea water at the bottom and runoff or outgoing tidal water nearer the surface, usually with a

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*See Figure 40

zone of mixing between. This reinforces the opinion of the current measuring crews that there is a substantial current difference, both in speed and direction, between layers.

An attempt was made to assess the carrying capacity of the Goose Cove ecosystem. Although difficult to quantify, community diversity is the best indication available of carrying capacity. The more rigid the environment is the fewer discrete species may be supported. Recently, several methods for quantifying diversity have been employed with success, for example, the rarefaction analysis of Sanders (Ref. 8) and the information function of Shannon (Ref. 9). This information function, Σ p log p, where p is the fraction of individuals of a certain species in a community is relatively easy to use because it is essentially sample size independent. However, it fails to quantify such important ecological diversity indications as community bio-mass.

Preliminary studies by Dow have indicated that forty species are present in the benthos near Goose Pond with two species making up 83% of the total number of individuals. Normally, a similar non-polluted ecosystem would be able to support approximately 80 species. Qualitative analysis of one benthic mud sample taken in Goose Cove during July, indicated an over abundance (a number of individuals far greater than would be expected in a stable, unpolluted ecosystem) of Capitella, a polychaete worm that is known to dominate communities in physiologically rigorous (usually polluted) marine habitats. Also, conspicuous by their absence were amphipods of the family ampeliscidae, usually the first to be eliminated during the pollution of an ecosystem. This radical decrease in diversity can probably be attributed to surface run-off from mine waste heaps. Lack of geological data discourages speculation about the water and heavy metal ion permeability of the rock strata below the volcanic surface rock. However, it is readily apparent that direct exposure of seawater to metal deposits would increase the heavy metal ion concentrations.and ecological damage by as much as an order of magnitude. Such damage could have profound economic effects on Hancock County and the Penobscot Bay area as a whole. This area is currently the world's most productive area for <u>Homarus americanus</u> the American Lobster, which is extremely susceptable to heavy metal ions, particularly mercury.

The mine is scheduled to close in December 1971, the commercially profitable ore having been exhausted in three years of operation. Among alternative solutions to the restoration problem, flooding Goose Pond with fresh water was proposed as well as opening it to the Bay. The town engaged the services of Dr. Ruth Patrick, an ecologist with the American Institute of Natural Sciences, noted for her work on community diversity, to recommend solutions to the ecological problem. Conversation with Dr. Patrick on the site indicated that she would consider covering the ore bearing strata in the open pit with benthic mud, possibly dredge spoils, which is relatively impermeable to ion transport. This would tend to minimize, but not eliminate an increase in ecological damage to the area, but it seems to be the most feasible alternative if the pond is eventually to be reflooded. In any case, the Pond in its present dry and waste filled condition, should not be opened to Penobscot Bay.

Time and financial limitiations prevented the undertaking of a through bioassay of the Goose Pond area benthos. This should be a primary goal in any future studies of the area, for it will yield a great deal of information at minimum cost.

Robert Dwyer
Paul Shapiro
Prof. Damon Cummings
13.90
September 1971

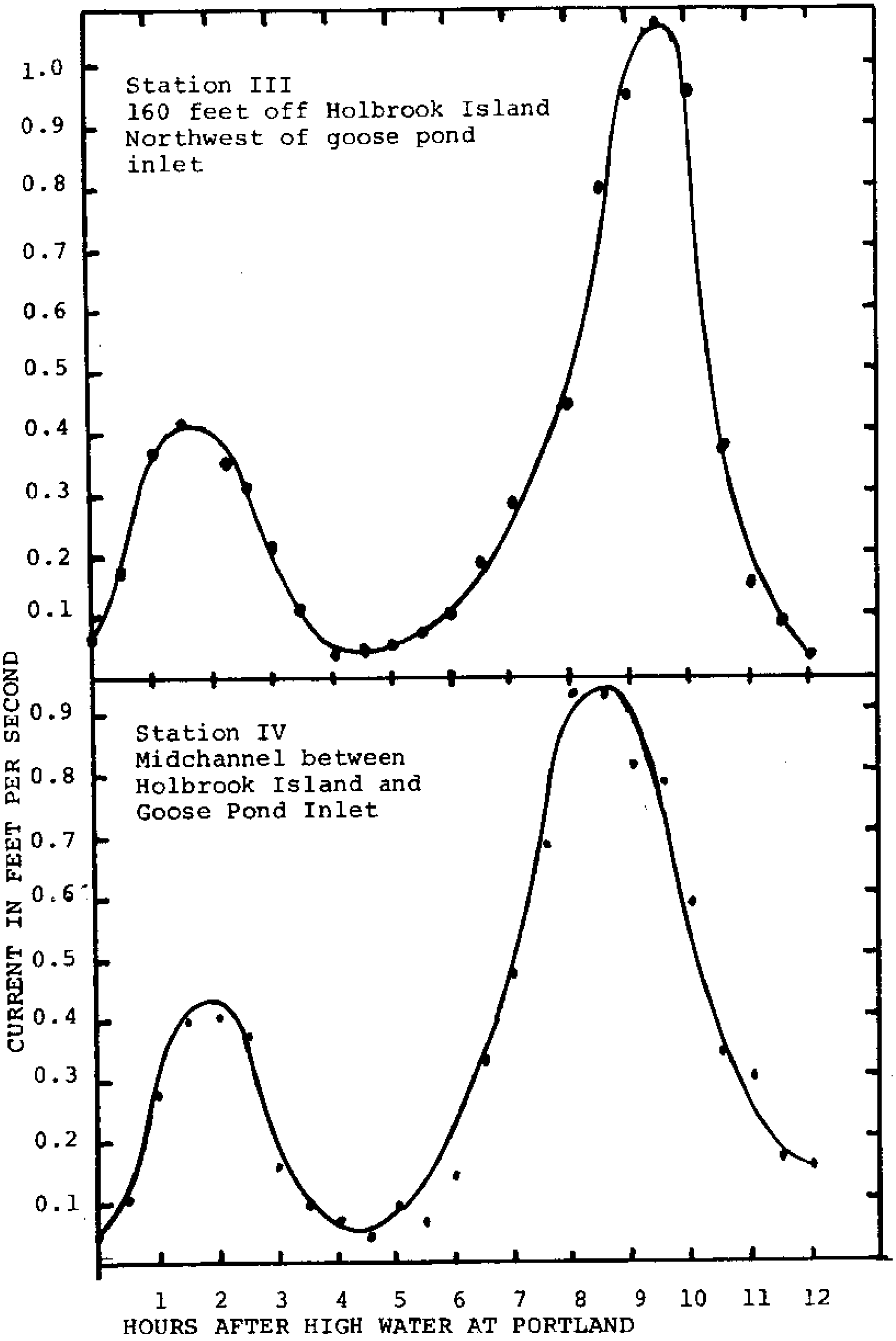

Station III
160 feet off Holbrook Island
Northwest of goose pond
inlet
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Station IV
Midchannel between
Holbrook Island and
Goose Pond Inlet
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
CURRENT IN FEET PER SECOND
1
2
3
4
5
6
7
8
9
10
11
12
HOURS AFTER HIGH WATER AT PORTLAND

FIGURE 37

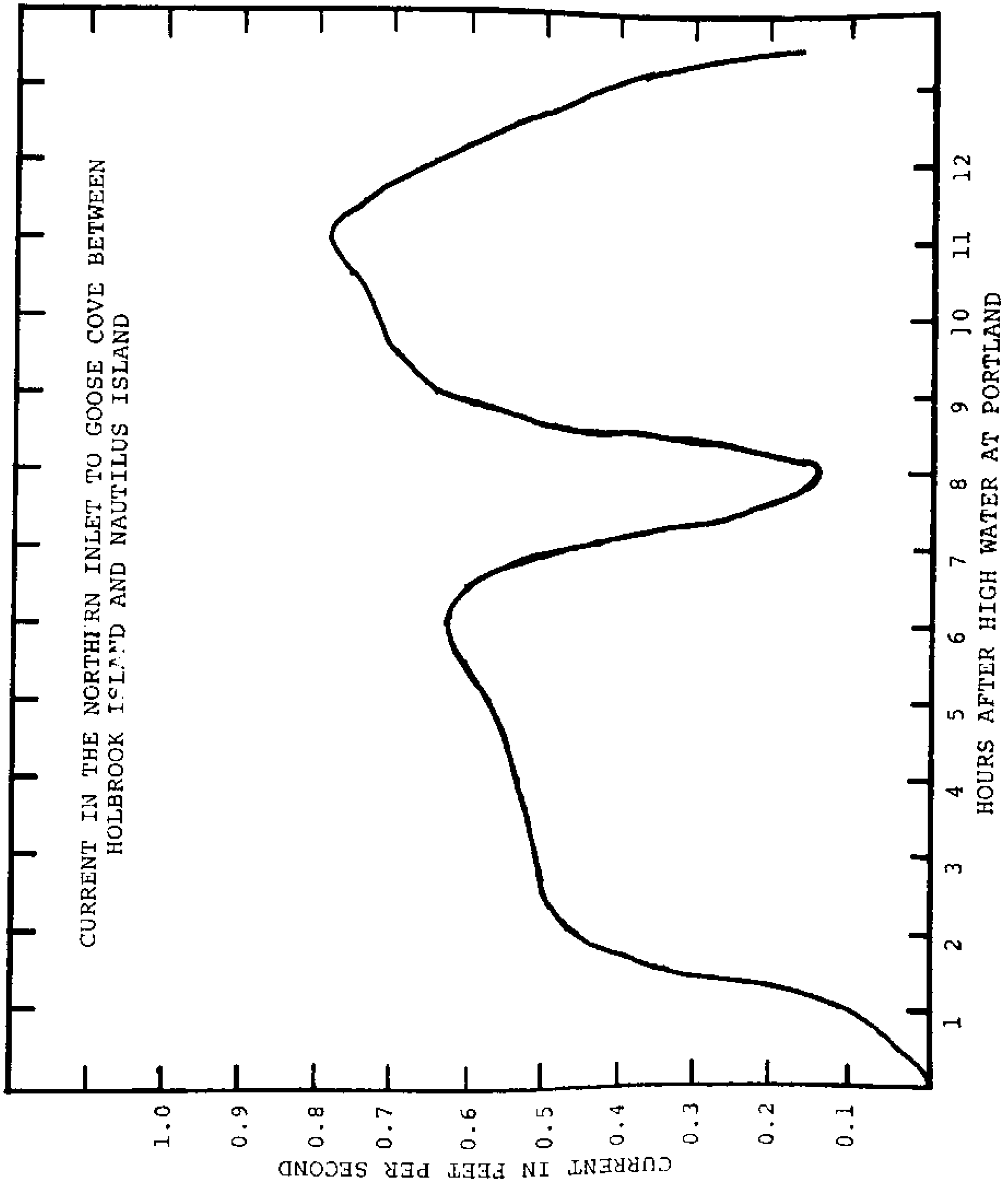

CURRENT IN THE NORTHERN INLET TO GOOSE COVE BETWEEN
HOLBROOK ISLAND AND NAUTILUS ISLAND
HOURS AFTER HIGH WATER AT PORTLAND
1
2
3
4
5
6
7
8
9
10
11
12
CURRENT IN FEET PER SECOND
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

FIGURE 38

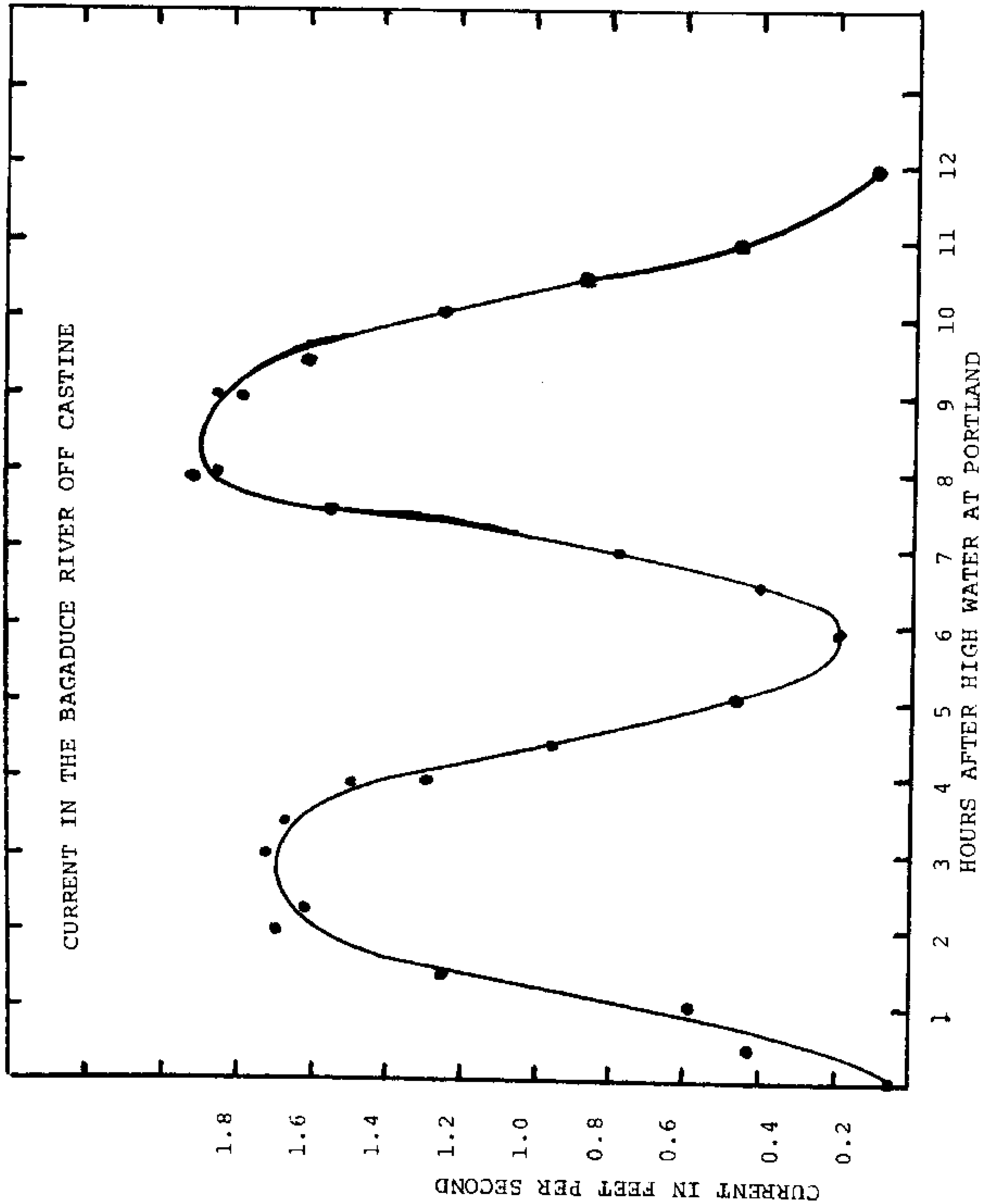

CURRENT IN THE BAGADUCE RIVER OFF CASTINE
CURRENT IN FEET PER SECOND
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
HOURS AFTER HIGH WATER AT PORTLAND
1
2
3
4
5
6
7
8
9
10
11
12

FIGURE 39

GOOSE POND STATION 2
July 9, 1971

		µ gram-atoms/liter			
Depth	Temperature(°C)	NO_2	PO_4	Si	NaCl(ppt)
surface	15.5	0.039	0.71	1.03	26.2
3 meters	10.5	0.045	1.24	1.70	28.70
6 meters	9.3	0.047	1.19	4.46	28.5
9 meters (bottom)	9.0	0.068	1.84	3.92	29.0

Secchi disk depth - 14.5 ft.

GOOSE POND STATION 2
July 15, 1971

Depth	Temperature (°C)	NaCl(ppt)	Dissolved O_2(ppm)
surface	15.5	26.1	10.58
9 ft.	13.5	25.8	
18 ft.	13.0	26.4	8.44
27 ft.	11.0	26.7	8.94
36 ft.	10.7	26.85	9.35
45 ft.	10.4	27.19	8.5

Secchi disc depth - 14.0 ft.

FIGURE 40

WATER QUALITY ANALYSIS IN THE PENOBSCOT RIVER ESTUARY

An attempt was made to trace the flow and dispersion of pollutants in the lower river and the upper part of Penobscot Bay. First, it was necessary to trace the flow and mixing of river water into the seawater of the bay. Coriolis force should push a body of water to the right of its direction of motion. This would imply that, on an incoming tide, the denser sea water should be piled up on the bottom of the east bank of the river, while fresher (and less dense) river water should dominate the west bank. An east-west transect across the river at Fort Point measuring salinity and temperature agreed with this hypothesis (see Figures 42 and 43). A transect between Dice's Head and Turtle Head (see Figure 41) was also made to gather temperature data in deeper waters farther south. This showed that below 10 meters, the bay water is unaffected by the mixing of river water (at about 10m, the temperature stabilized at about 10°C down to the bottom; any mixing with the warmer river water would have caused some temperature variations in this deep water layer).

Once an approximate pattern of the dispersion of river water into the bay had been determined, a water sampling cruise aboard MMA's 50 ft. Oceanography Vessel Aardvark was made up the river as far as Winterport (see next section for data and analysis).

Samples were analyzed at MMA for salinity and dissolved oxygen, while the remaining analyses were performed at M.I.T.

In addition, temperature (using Bathythermograph and surface temperature thermometer) and visibility (using a standard oceanographic Secchi disk) were recorded in situ. Visual documentation of major pollution sources was also made (see accompanying photographs).

The major source of pollution on the part of the river the covered during the cruise was the St. Regis Paper Mill at Bucksport. According to the 1967 Department of Interior report, St. Regis and Standard Packaging Corporation in Bangor (which has since gone out of business) are the major sources of suspended solids, BOD, and sulfite waste liquor, on the river.

Cleaning the pollution caused by the plant is an expensiv proposition. Forcing the plant to shut down is no solution - the town of Bucksport would be destroyed economically. The solution to this problem lies more in political and economic hands than in scientific ones, so it will not be explored further here.

Robert Dwyer
13.90
September 1971

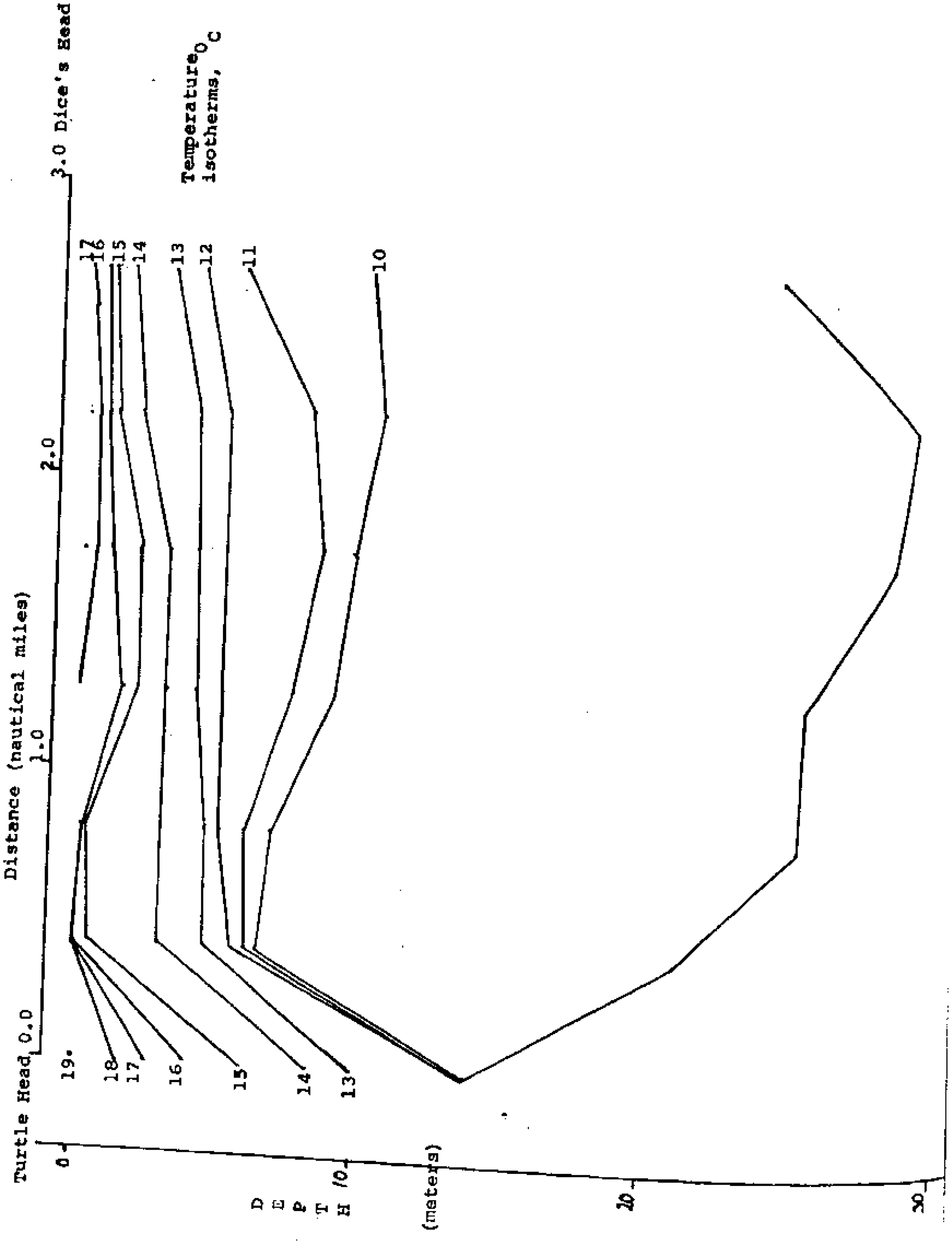
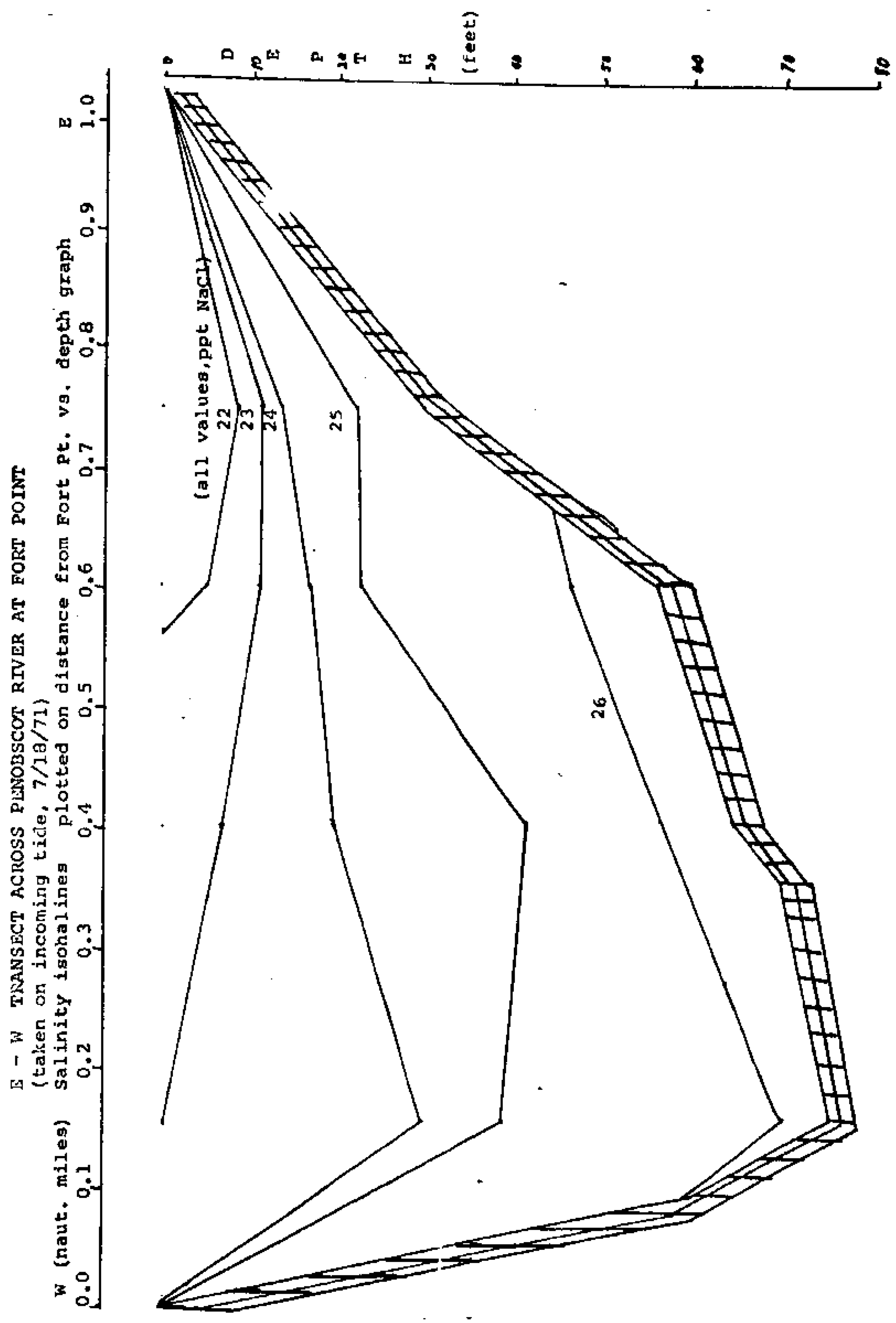

Turtle Head 0.0
Distance (nautical miles)
1.0
2.0
3.0 Dice's Head
Temperature isotherms, °C
19
18
17
16
15
14
13
17
16
15
14
13
12
11
10
DEPTH (meters)
0
10
20
30

FIGURE 41



E - W TRANSECT ACROSS PENOBSCOT RIVER AT FORT POINT
(taken on incoming tide, 7/18/71)
Salinity isohalines plotted on distance from Fort Pt. vs. depth graph
(all values, ppt NaCl)

FIGURE 12

E - W TRANSECT ACROSS PENOBSCOT RIVER AT PORT POINT
(taken on incoming tide, 7/18/71)
Temperature isotherms (^oC) plotted on distance from Port Pt. vs. depth graph

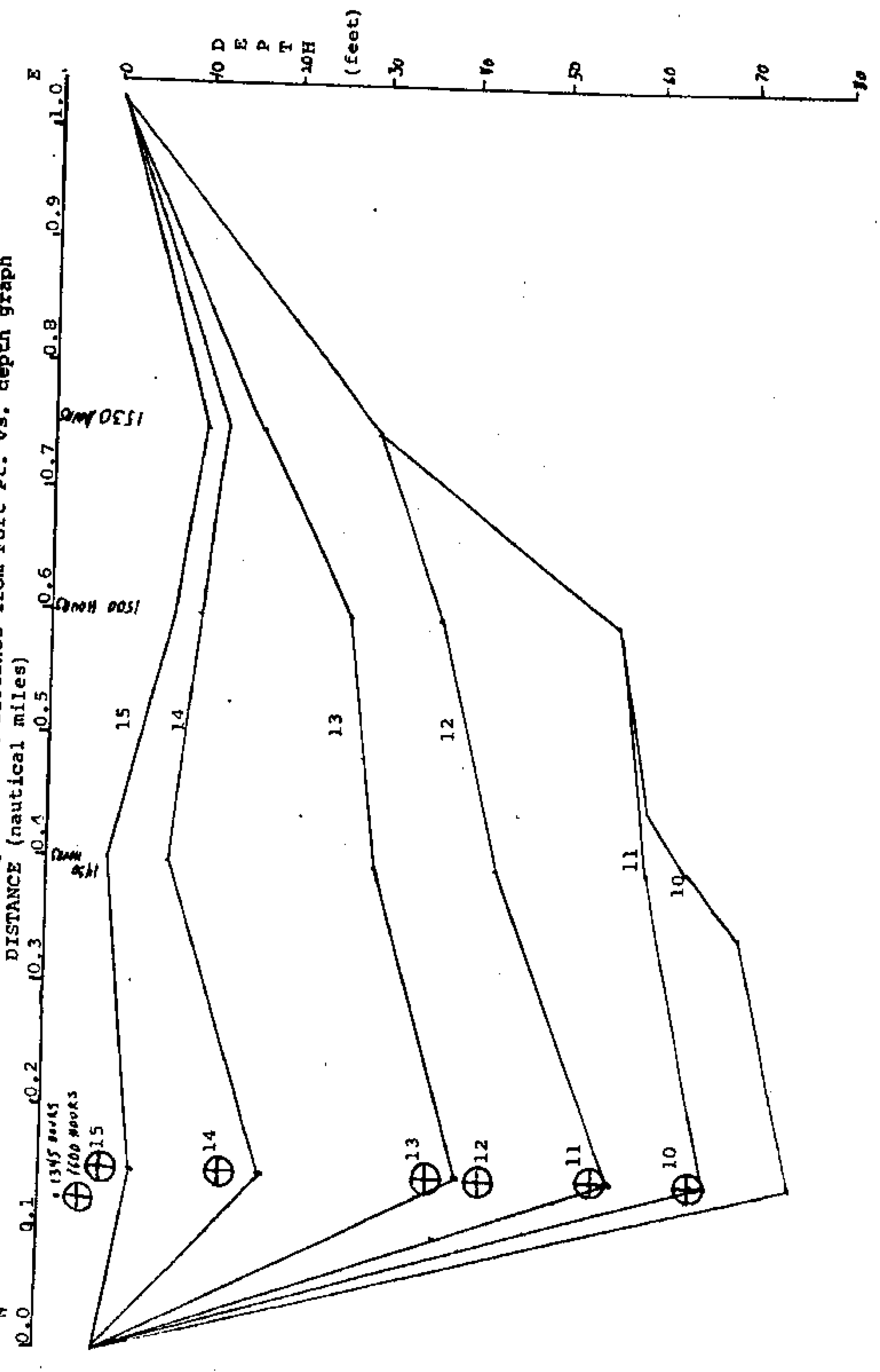


FIGURE 43

DETAILS OF PENOBSCOT RIVER ANALYSIS

On Sunday, July 25, 1971, a sampling cruise was made up the Penobscot River. Samples were taken between the southern tip of Verona Island and Winterport (see Appendix A and Figure 42). Of the 9 stations samples, Station #6 shows t most radical departure from nonpolluted water conditions. This station is twenty feet off the St. Regis Paper mill outfall. Residents say that the pollution is worst on Sundays, when the mill management is certain that no Environmental Protection Agency investigators are nearby.

Dissolved oxygen and salinity were both measured using modifications of methods described by APHA (Ref. 1) and Strickland and Parsons (Ref. 11). Dissolved oxygen was titrated iodometrically. Chlorinity was measured using silver nitrate titration. Phosphate, nitrite, and silicon were measured by standard UV absorption spectrophotometery. Due to lack of time, sulfite and trace metals, both major pollution problems on the river, were not assayed for this report. Supplementary data will be available as soon as time permits further analysis of the river samples.

One can easily note the difference in the phosphate, nitrate, and silicon levels between the Penobscot stations and Goose Pond II (see Fig. 40). It should be noted that Goose Cove is also part of an estuary system (albeit much smaller): the Bagaduce River. Normalized to a water volume flux equal to that of the Bagaduce, the Penobscot River is still many times more polluted than the outer parts of the Bay. Considering the large watershed of the River, it is evident that dispersion of the River's pollutants into the Bay and the open sea has the potential for great ecological damage. Quantifying the damage already done, and predicting any future damage, should have priority in any future oceanographic studies of the area.

Robert Dwyer
13.90
September 1971

PENOBSCOT RIVER SAMPLES

July 25, 1971

Sample and Station # (see chart)	Temperature (°C)	Secci Disk Depth	PH	Dissolved Oxygen (rpm)	µg-atom/ℓ PO$_4$	µg-atom/ℓ NO$_2$	µg-atom/ℓ Si	NaCl (ppt)
#1 surface	17	6 ft.	6.8		.706	.491	14.8	20.5
#1 bottom (8m)	13		6.5		.691	.161	5.32	25.05
#2 surface	16	6 ft.	6.5		.711	.386	13.6	20.0
#2 bottom (9m)	12.6		6.5		.889	.217	6.34	26.2
#3 surface	16.7	6 ft.	6.0	7.31	.631	.367	17.4	19.65
#3 below surface (6m)	15		6.0		.681	.266	5.97	23.5
#3 bottom (12m)	13		6.0	7.28	.726	.2[illegible]	6.25	25.0
#4 surface	18.5	5.9 ft.	6.5		.631	.397	22.7	17.9
#5 surface	17.7	5 ft.	6.5	6.05	.775	.334	12.6	20.2
#5 bottom	14.9		6.3	6.95	1.17	.435	11.8	22.9
*#6 surface	16.5	4 ft, 2 ft	6.5	8.20	1.04	.364	12.5	21.7
*#6 bottom (15m)	13.5		6.5	4.34	2.22	.592	9.70	24.2
#7 surface	18	5 ft.	6.3	6.42	.825	.307	21.0	18.2
#7 bottom (14m)	13		6.3		1.32	.262	9.61	24.3
#8 surface	19.5	3.5 ft.	6.0		.785	.382	29.2	14.7
#8 bottom (8m)	18		6.0		1.89	.746	28.0	16.1
#9 surface	17	5 ft.	6.0		.770	.300	19.5	18.7
#9 bottom (10m)	14.5		6.5		.929	.266	12.3	22.25

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* 20 feet off St. Regis outfall

FIGURE 44

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SEARCH PROJECT INTRODUCTION

The search for a 30' Shields class sloop lost in the fall of 1970 in Penobscot Bay turned out to be the most time consuming part of the summer laboratory. The first problem to be encountered, a major one by any standards, was the large search area. No one saw the boat go down and the last sighting is estimated to be 15 minutes before the boat was lost. This gave an area much too large to be covered with the time and equipment to be used. With the help of Prof. Wyman, using the known wind at the time of the accident and the probable course of action of the crew, a smaller, higher probability search area was decided upon.

The size, shape, and construction of the boat made only one type of instrumentation useful, sonar. Any magnetic or gravitational anomaly produced by the sailboat would be much too small to be detected. The visibility in the area, often limited to 5' or 10' prevented the use of diver sleds and would have limited the use of cameras had they been available. The bottom being mostly flat mud was favorable for the use of drags, but due to the probable position and the shape of the Shields a drag was as likely to pass over it as snare it. Two types of drags were used. One was simply a 10' bar which proved relatively easy to handle and did succeed in snagging known objects. It was, however, limited by the small area it was able to cover. The other drag system consisted primarily of 300' of small chain. This system was more complicated, since it required the use of two boats, but the area covered was many times that of the drag. The effectiveness of the drag was never proved, but it did prove to be a very good anchor on a flat mud bottom.

Most of the search was carried out with sonar. Two weekends before July, searches were made using Dr. Edgerton's side scan and down-looking fathometer.

Dr. Edgerton ran the sonar the first weekend while Dr. Dyer worked the second weekend. No diving was done during this period, but all targets were marked on the chart as precisely as possible. At this time, as well as in July, transit stations were established on-shore and used for navigational purposes. In July, the only instrumentation available was a recording fathometer. This is a "single line" device with obvious limitations when it comes to searching large areas. The usefulness of this device was greatly increased when under the direction of Dr. Dyer, it was converted to a side scanning sonar.

During July, targets were marked with buoys and then divers were sent down to perform a circular search around the buoy and determine what the target was. This procedure was very frustrating because very often the divers were unable to locate what the sonar clearly showed. The lack of visual confirmation remains unexplained.

As Captain Searle stated several times, due to lack of time, equipment, and information, it was unlikely the sloop would be found, but the learning opportunities were well worth the investment. Only by conducting an actual search, can the difficulties of operating on and in the water be appreciated. Problems of weather, navigation, and even precise recollection of what was done where can be problems as can many other apparently simple aspects of the search.

John Schenck
13.90
September 1971

SONAR CREW SEARCHING

FIGURE 45

SEARCH PATTERN

The primary objective of the search conducted as a part of the project was to find and retrieve, if possible, the Shields sailboat lost in October 1970, but a secondary objective, which was the primary accomplishment, turned out to be extremely important and rewarding. The general knowledge of search techniques gained by all those involved with the project overshadowed the disappointment felt in not finding the boat.

The search for the boat consisted of three distinct phases - two weekends of intensive probing in May and June, and the search conducted in July when work was also being done with underwater recording equipment and biological testing.

On the first weekend, May 21-23, Dr. Harold Edgerton, accompanied byaabout 10 students from M.I.T., used his side-scan and down-looking sonar to search the bay for the sailboat. The side-scan, which looks off the side to an approximate distance of 500 feet uses a high frequency signal to reflect objects on the bottom. The vertical sonar uses a low frequency signal to reflect a small area directly below the search boat, and records sublayers below the bottom surface. Dr. Edgerton was interested in the bottom profile and structure of the bottom surface layer besides the sighting of the Shields boat.

No divers were used during the search operation of the first weekend, so the objective was simply to sight and catalogue targets using the sonar so that a more thorough visual search could be conducted later. The major accomplishment of the weekend was development and refinement of techniques of searching and navigation and communication.

The method of attack that weekend was to set up a transit station on the Isleboro Shore and make search runs directly east across the bay, then back along the same transit line to the station, since the side-scan transducer only looks off to one side of the boat. Each round-trip run would take at least an hour and a half, and more than thirty minutes were required for the purpose of changing transit stations. One run would be made at each transit station before moving on down the bay to the next station. Since the total bath width covered on a transit run is 1,000 feet and since the transit station used were approximately a mile apart, it is obvious that on the first attempt at the search, it was not the object to cover a small area intnesively.

On a search run, information such as the angle of the transit from a prominent point, the time of day, and the speed of the boat, were recorded on the sonar printouts, so that at the sighting of a target, approximate location could be established.

The first day was the most ideal for the search, but the degree of accomplishment was slight due to inexperience in search methods. Work on the second day was very much restricted due to fog and rain. Work the third day was limited by high seas and an early return to Boston. Approximately, seventeen hours were spent on the bay the first weekend in search of the sailboat.

The next weekend of searching was headed by Dr. Ira Dyer. Dr. Dyer, assisted by four M.I.T. students and several M.M.A. personnel, used Dr. Edgerton's side-scan sonar for the search. Again, no divers were used as a visual check on sighted targets. The primary difference between the two weekends was that Dr. Dyer concentrated the search intensively on an area that was considered to have the highest probability for finding the sailboat.

Much discussion of the conditions surrounding the loss of the Shields boat and resulting probability density functions preceded any actual searching that weekend. The probabilities were determined through the assistance of Lt. David Wyman M.M.A. using information presented before the board of inquiry and by use of general knowledge of sailing and human action. An area was selected for the weekend search that was small enouc to be thoroughly covered in two days. The depth of the water in this area was less than 100 feet, which was more conducive to eventual visual confirmation of targets by divers. The area of the search was north of Hewes Point between Hewes Ledge and Isleboro Ledge.

Transit Station #3 was used for the whole operation with runs made in a fanning direction from the station. A hand bearing compass was used to determine the correct points for turning around at the end of a run and for helping to pinpoint a target location. The data recorded on the sonar printout was the time of day, speed of boat, angle of transit run in degrees from Hewes Point and hand bearing compass readings.

Many targets were sighted during the weekend and a few were found more than once from different runs. Even several of Dr. Edgerton's targets were believed to have been rediscovered.

The method of search during July was quite unlike the weekend search in several aspects. No new areas were investigated, but instead the area in which both Dr. Dyer and Dr. Edgerton found the most targets was searched for the purpose of again finding those targets and using divers to visually check out each. With the M.M.A. recording fathometer being used as a down-looking sonar, runs were made north of Hewes Point. A grapple of ten foot width and a small chain dragged between two boats 200 feet apart were also used in the attempt to find targets.

The navigation and communication technique was similar to that of the two weekends. Patterns were run using a transit on shore and a second transit station and a hand bearing compass on board the boat were used to help pinpoint any targets.

At the sighting of a target on the sonar printout, a concrete block anchor attached by line to a surface float was immediately thrown overboard to mark the spot. Runs were then made in a circular pattern about the marker float in an attempt to confirm the target sighting. Then the anchor of the search boat was placed as closed to the target as possible and the anchor line was used as a descending line for the divers. Two divers swam down to the anchor to which they attached a search line of approximately 100 feet. The buddy pair then stretched the line out and swam in a circular motion about the anchor. The visibility varied between 5 and 10 feet, so the visual range was small. If the line became snagged during the search pattern, then the divers would swim along the line towards the anchor to investigate. If they found the Shields boat, they would tie into the boat then proceed back up the anchor line to notify the surface crew. If their investigation of the snag proved negative, the divers would unhook the line and proceed to complete the search.

The area covered during such a dive is a little less than an acre, but it was found to be a quick, easy method of covering a possible target locale when visibility is restrictive.

Once an area had been covered by the divers, the marker buoy was retrieved and the search boat returned to the transit line that it had left and the continuing surface search.

In more than 100 hours of search time spent actually out on the water, much area was covered and quite a bit about search techniques was learned by all the participants.

Fred Horr
13.90
September 1971

NAVIGATION AND COMMUNICATION

In conducting the search for the lost Shields class sailboat, it was necessary to develop a workable navigation and communication system in the absence of sophisticated, expensive equipment, which was unavailable to the project. The object of the system was to cover a planned course or area and to know at all times the location of the search boat for the purpose of pinpointing targets.

On the Isleboro shore, convenient locations near the highest probability search area were selected as transit stations. Each day before the search began, a shore party of two people per transit station was put ashore. If the communication radio was functioning adequately, one person could handle the total shore operation, but it was better for two people to be ashore in case of communication breakdown and for rest breaks from the transit sighting. Prominent points on the opposite shore, such as Hewes Point or Cape Rosier, were used to orient the transit, and the runs of the search pattern were made at specific angles from these points.

With the transit fixed at the prescribed angle, runs straight across the bay were made by the shore party communicating to the search boat any necessary course corrections. These communications usually consisted of a command to head a certain number of boat widths in the direction back toward the cross hairs of the scope.

TRANSIT STATION

SONAR BOAT ON TRANSIT LINE

SONAR BOAT
THROUGH TRANSIT

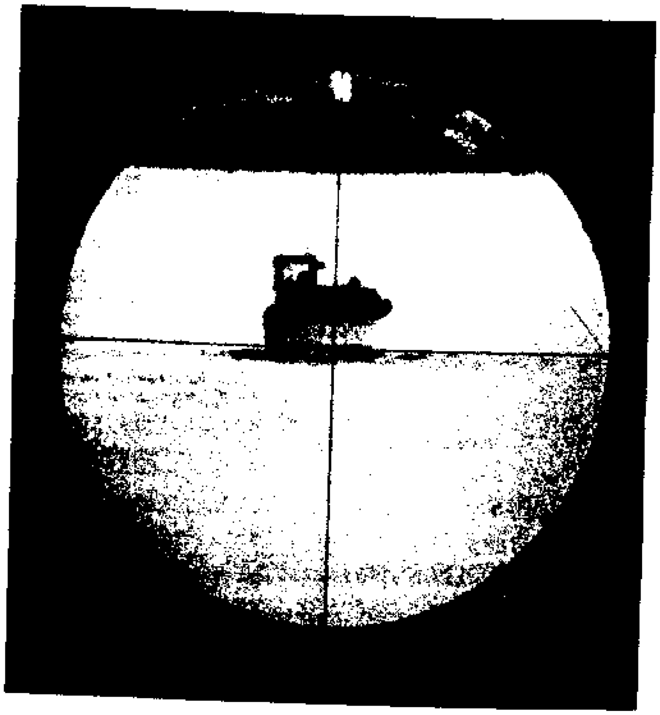


FIGURE 46

Occasionally a second transit station was set up at least several hundred yards from the primary station for the purpose of accurately pinpointing target locations. The second station was also useful in determining the correct spot to turn around for runs that did not run from shore to shore.

On the search boat a hand bearing compass was often used along with or in place of the second transit station. The compass is not extremely accurate for the purpose of establishing a target location, but it is helpful in determining the starting and ending point of the runs.

The communication part of the system primarily consisted of voice commands over two way radios. When the radios were functioning correctly, this system proved very adequate to the needs of the search. Even with four radios in operation - two on shore at the two transit stations, one on board the primary search boat, and one aboard the dive boat - the system worked extremely well after all the users became practiced in the most efficient method of radio communication.

It was necessary to create a back-up system because occasionally the radios were not functioning correctly, due to moisture in the air or the fact that the batteries had not been recharged adequately. One method used a few times was a simple signal mirror. The mirror was adequate for communicating course corrections from the shore to the boat, but was not sophisticated enough, at least under our unrefined usage, for any other purpose.

A flag system, using orange life jackets, orange foul weather gear, or white towels, was also developed, and proved to be adequate at reasonable distances (about a mile) on clear days. This system was not generally well accepted because it required much effort on the part of the shore party.

The navigation and communication system, although very simple in design, proved extremely capable under the requirements of our search techniques. One drawback was a dependency on weather conditions. In fog, transit sightings, and consequently precise search patterns, were impossible, so all searching was curtailed. In heavy seas on runs other than directly into or with the waves, navigation along the correct transit line was extremely difficult. This fact prompted the decision that the hours for search days run from sunrise (5:00 A.M.) until early afternoon, for the wind on Penobscot Bay does not usually blow up until middle or late afternoon.

This phase of the summer project was a good educational experience, and nearly everyone was involved in its operation at one time or another. The system is one of the most simple forms of a control system, yet, it provided much insight into the complexities of designing a control mechanism. Even under the most ideal conditions, that is, when a person on shore sighting the transit could communicate by radio directly to the man at the helm of the search boat, it still took some practice working together before a straight run could be maintained. The less ideal systems were much more difficult to use.

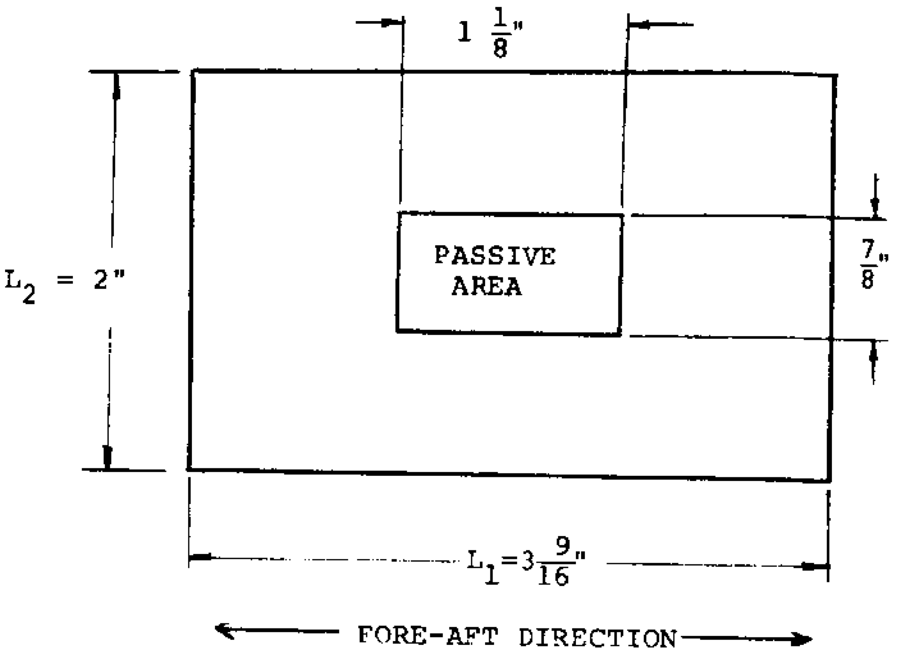
Fred Horr
13.90
September 1971

SIDE SCAN SONAR

Prior to the time the project actually moved to Castine, Maine, a determination was made as to the most probable area for finding the Shields sloop which we were to locate. Two preliminary trips were made to this search area to obtain records with a side scan sonar belonging to Professor Edgerton of M.I.T. The records so obtained, indicated a rather smooth bottom with some long depressions, 10-15 feet deep. They also indicated a significant number of probable targets whose locations were recorded. Most were in 60-100 feet of water (MLW datum).

Unfortunately, Professor Edgerton's sonar was not available for the actual laboratory and we were dependent on a Kelvin-Hughes recording echo sounder MS.37. This was a device which operated at 48 KHZ with a transducer dimension (length) of approximately 4 inches. This instrument was used in the area where we had found previous targets, but without much success. We were able to get target spikes off the bottom layers, but found it almost impossible to get them again on a repeat pass even with the aid of intersecting transit lines. Divers put down at the recorded location and completing radius search patterns located nothing.

Dimensions on the stock transducer provided with the system were as follows:



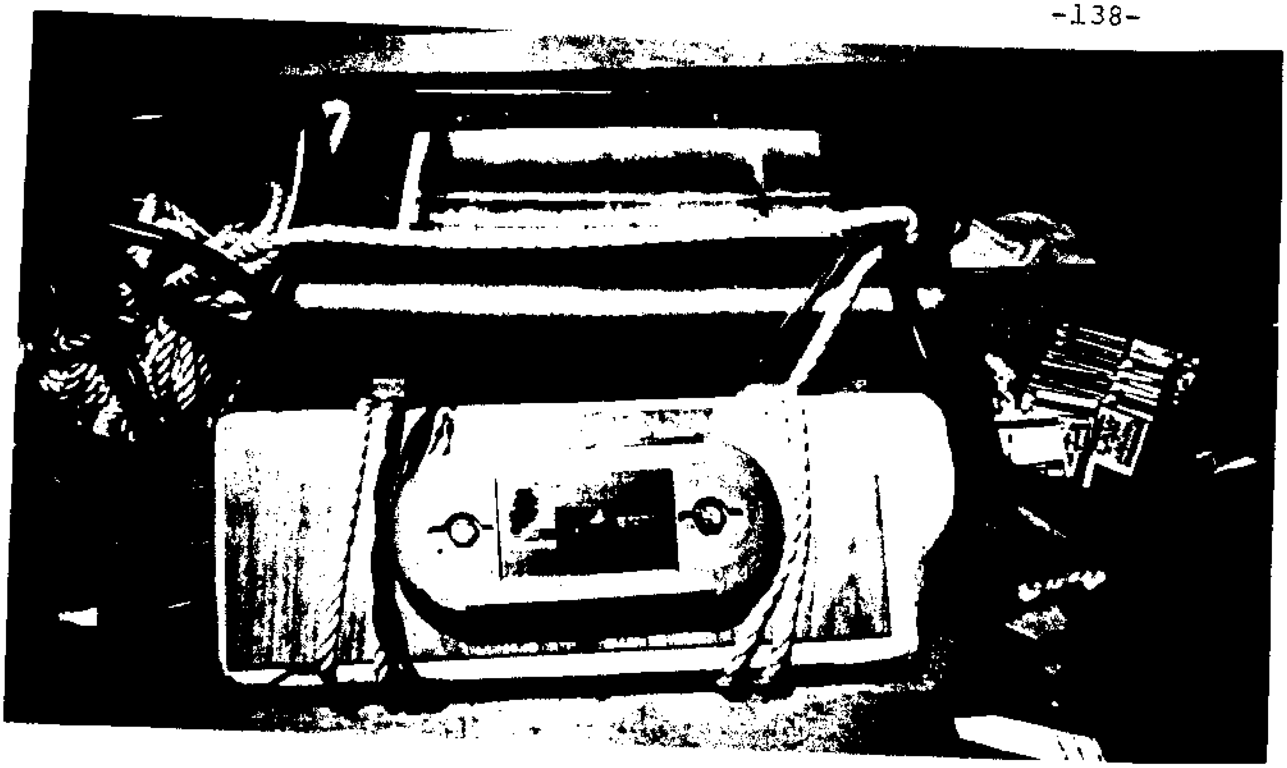
We were working with a 48 KHZ system which gave us a wavelength equal to $\frac{4,800}{48,000} = \frac{c}{f} = \frac{1}{10}$ ft.

Or, determining the angular projections in both the fore-aft (θ_1) and athwartship (θ_2):

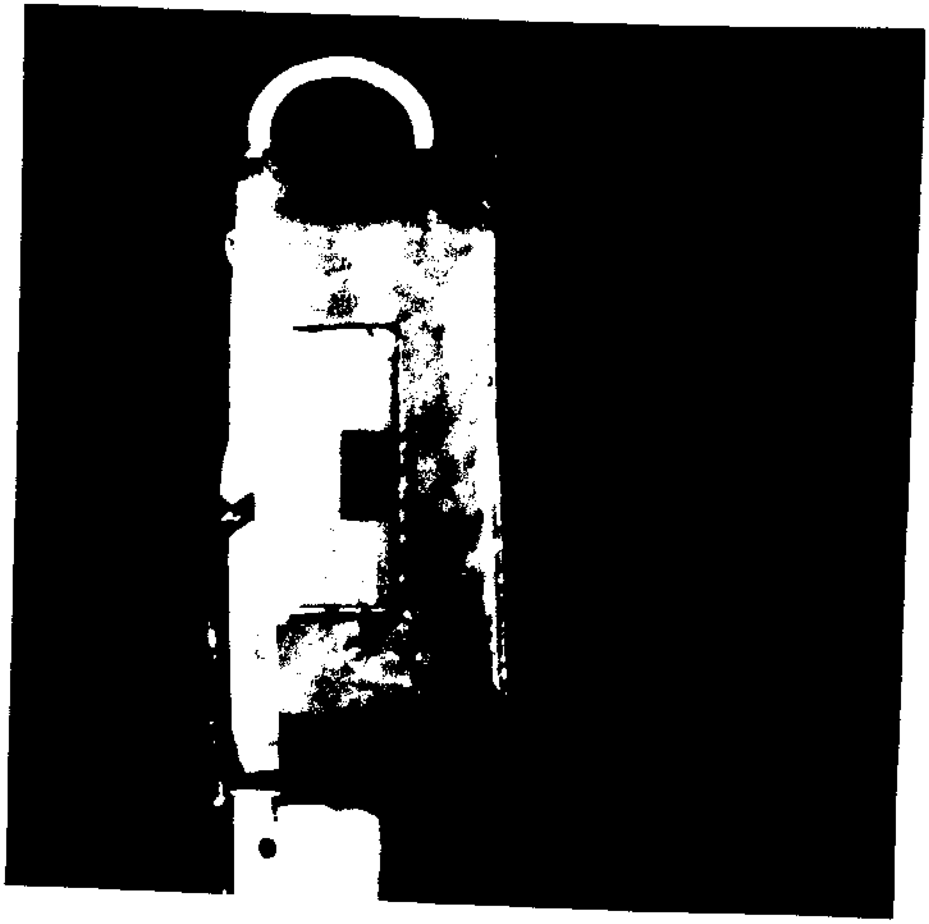
$$\sin\theta_1 = \frac{\lambda}{L_1} = \frac{(0.1)12)}{3.57} = .335 \qquad \theta_1 \cong 20°$$

$$\sin\theta_2 = \frac{1.2}{2} = .600 \qquad \theta_2 \cong 37°$$

What we proposed to do to modify this unit into a side scan sonar was to increase the athwartship angle to something a little less than 90° so as to be able to side scan the area from directly below out to off the beam as far as the power of our unit would allow. Additionally, we



ORIGINAL
FATHOMETER



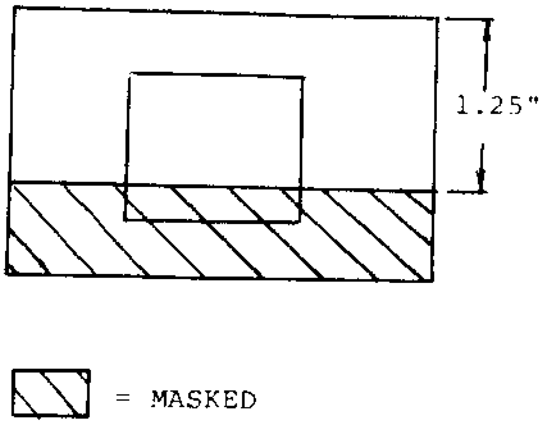
FATHOMETER
MASKED FOR
SIDESCAN
USE

FIGURE 47

would like to decrease our fore-aft angle to something like 5° for the principle lobe without any significant side lobes.

For the Athwartship Angle (Vertical)

L_2(in.)	$\sin\theta_2$	θ_2
1.50	0.8	52°
1.20	1.0	90°
1.30	0.92	65°
1.40	0.86	60°
1.25	0.96	70°



The above calculations made us choose to mask the lower indicated portion in an effort to obtain a vertical angle from directly below to 20° below the surface (see Fig. 47). Hopefully, this would avoid surface scattering effects.

For the Fore-Aft (Horizontal Plane) Angle

The problem with this angle was to decrease it through increasing the length of the transducer. This brings up two problems:

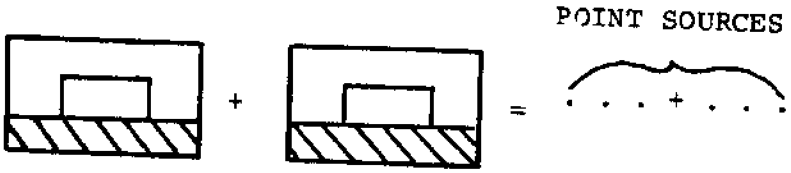
1) Tuning the new length transducer to the natural frequency of the original device.

2) Determining the best length for the distance between the two individual transducer units.

Tuning the transducer:

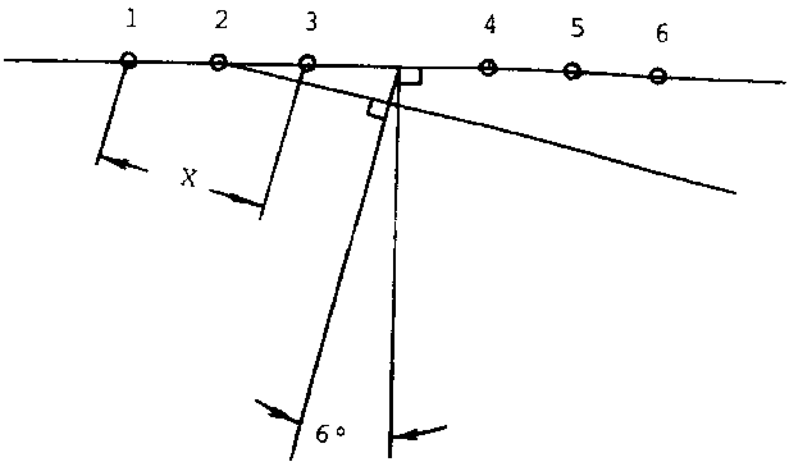
In increasing the length of the transducer, we halved the amount of inductance which required the addition of twice the original capacitance to maintain $\sqrt{LC}$ constant. This was done.

Determining the best length was done by modeling the device as pictured:

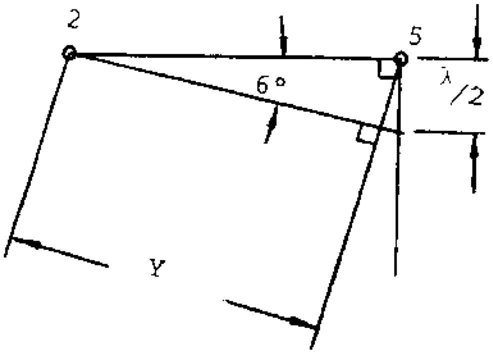


One of the limiting cases was determined by the geometry of how close the transducers could be placed. This resulted in a separation of 0.125 ft. and yielded the power transmission pattern shown.

The other separation was determined by noticing that at 6° the distance "x" is almost 1/2 wavelength and



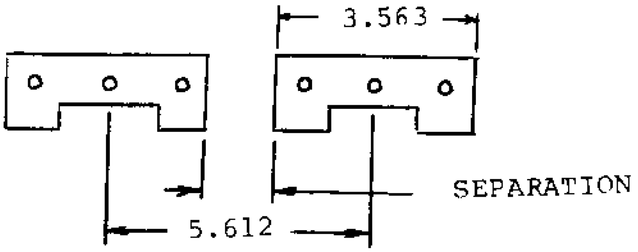
results in cancellation of point sources 1 & 3 and 4 & 6. This leaves point source 2 & 5. Estimating that we need a beam for searching of about 6° width at the 3dB-down point and assuming that actual beam width at 3dB-down half what the width is at null, we can determine separation:



$$\frac{\lambda}{2} = \frac{1.2''}{2} = 0.6''$$

$$\sin 6° = \frac{0.6''}{Y}$$

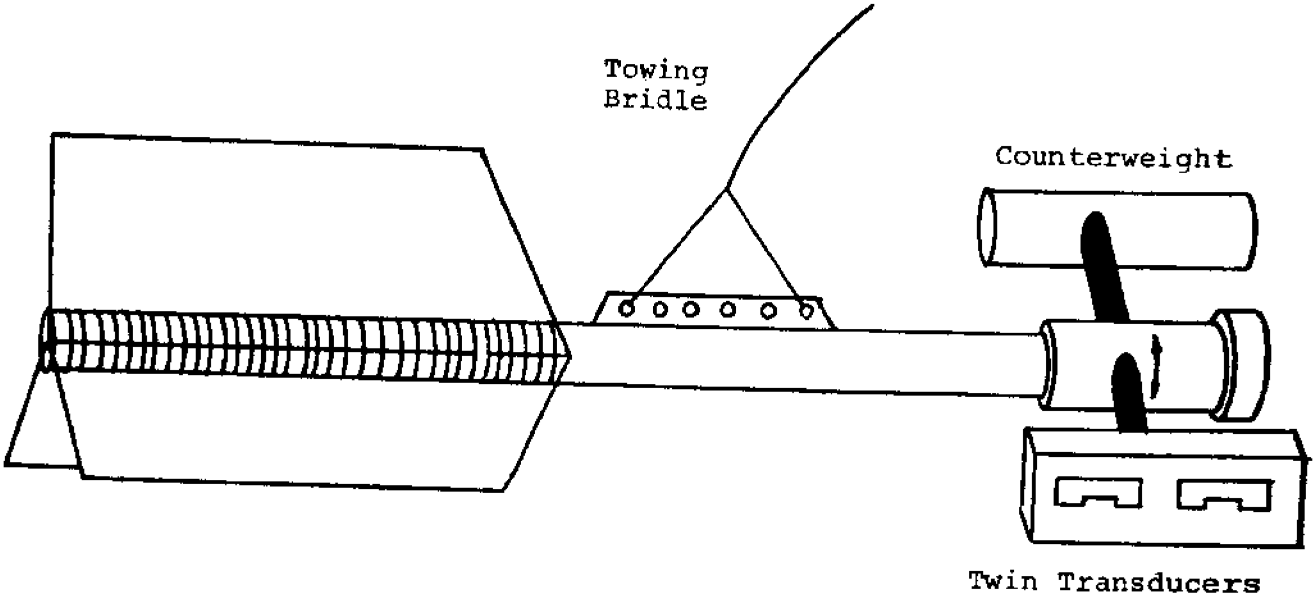
$$Y = \frac{0.6}{\sin 6°} = \frac{0.6}{.01093} = 5.612$$



$$\text{SEPARATION} = \begin{array}{r} 5.612 \\ \underline{-3.563} \\ 2.049 \end{array} \text{ in.}$$

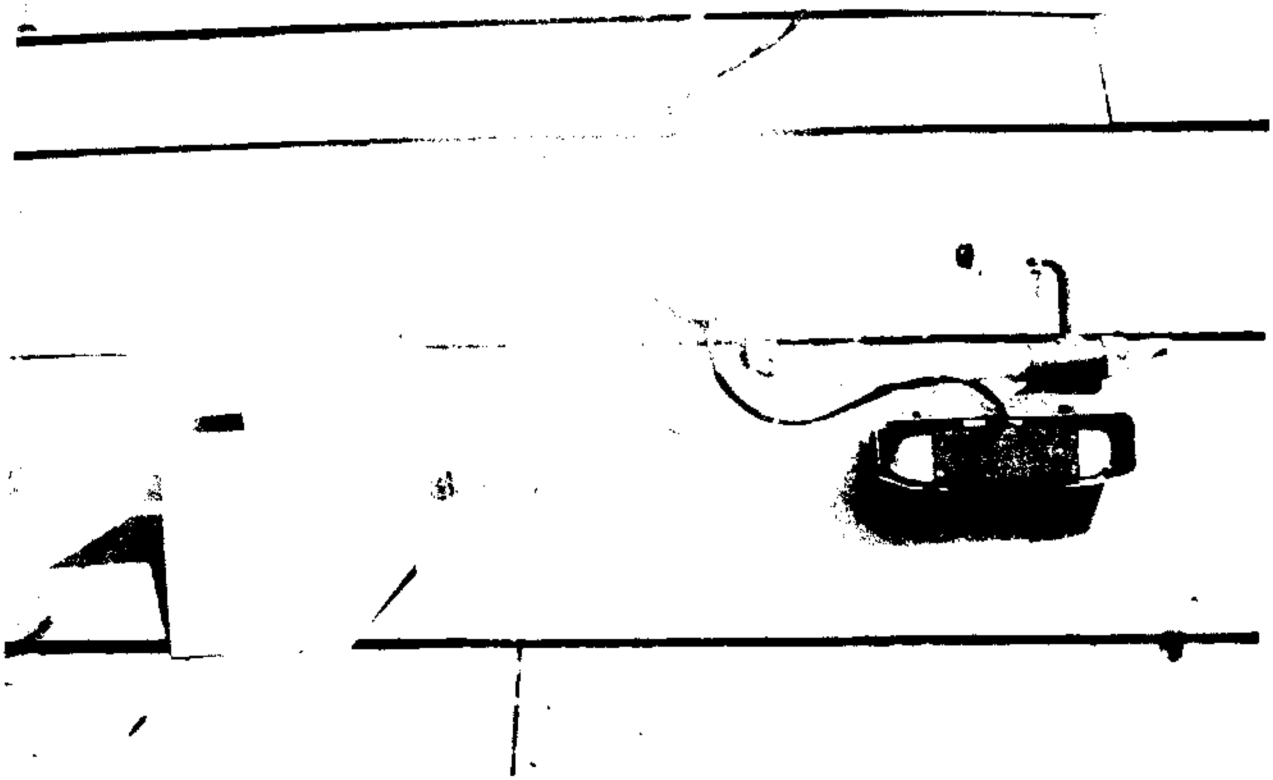
A computer run was made with this separation and indicated that the side lobes were only 10dB down vs. 13dB for the first configuration. Searching beam width was approximately the same.

To further decouple the motion of the transducer from that of the boat, it was determined to mount it on a fish which would be flown at a depth to avoid surface scatter problems (see Figure 48).



It weighed about 22 lbs. and was 3 ft. in length. The fish was stable at depths to 15 feet and speeds up to that of our work boat about 6 kts.

A computer program was run on both configurations of the transducers and are reproduced here. The .125 separation configuration was chosen due to the lesser magnitude of the side lobes.



SONAR FISH WITH SINGLE TRANSDUCER AND MASK

SONAR FISH WITH DOUBLE TRANSDUCER

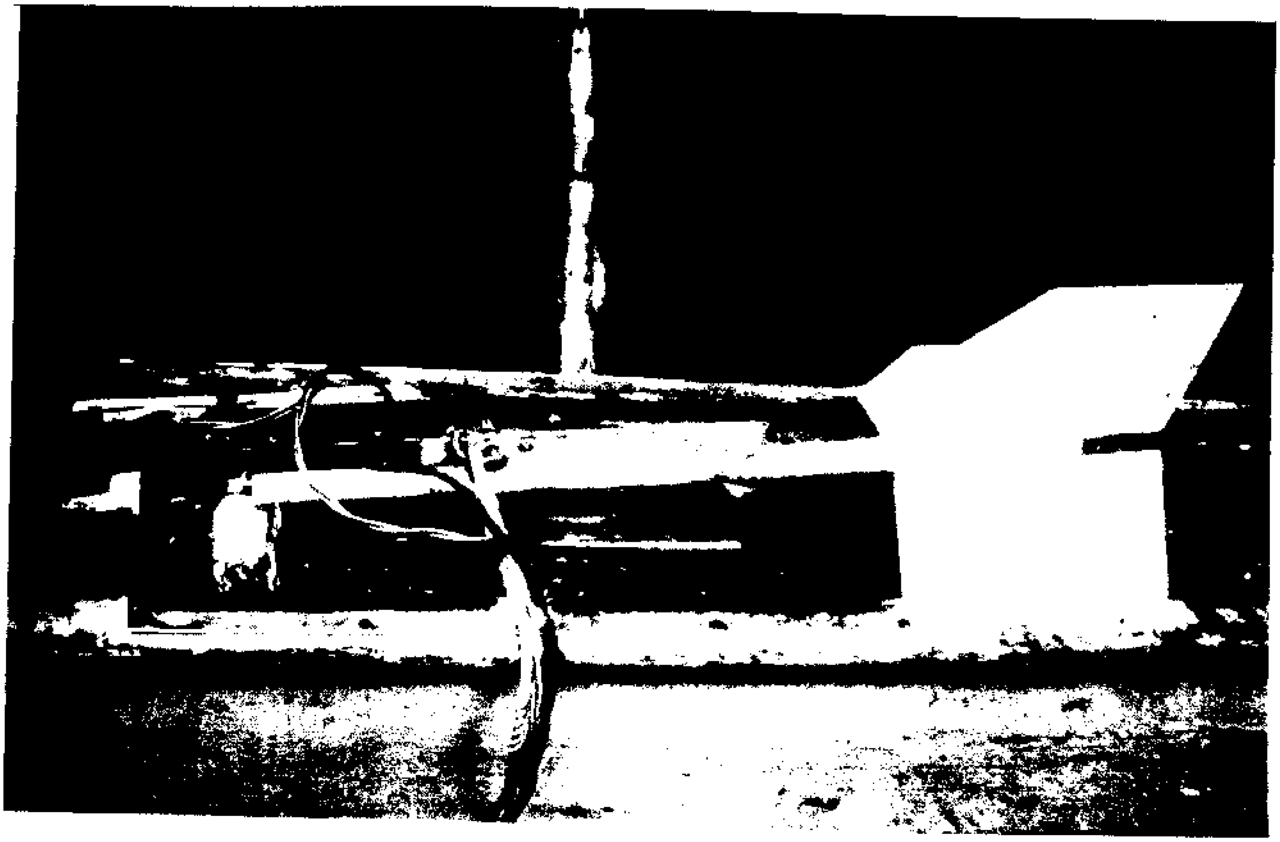
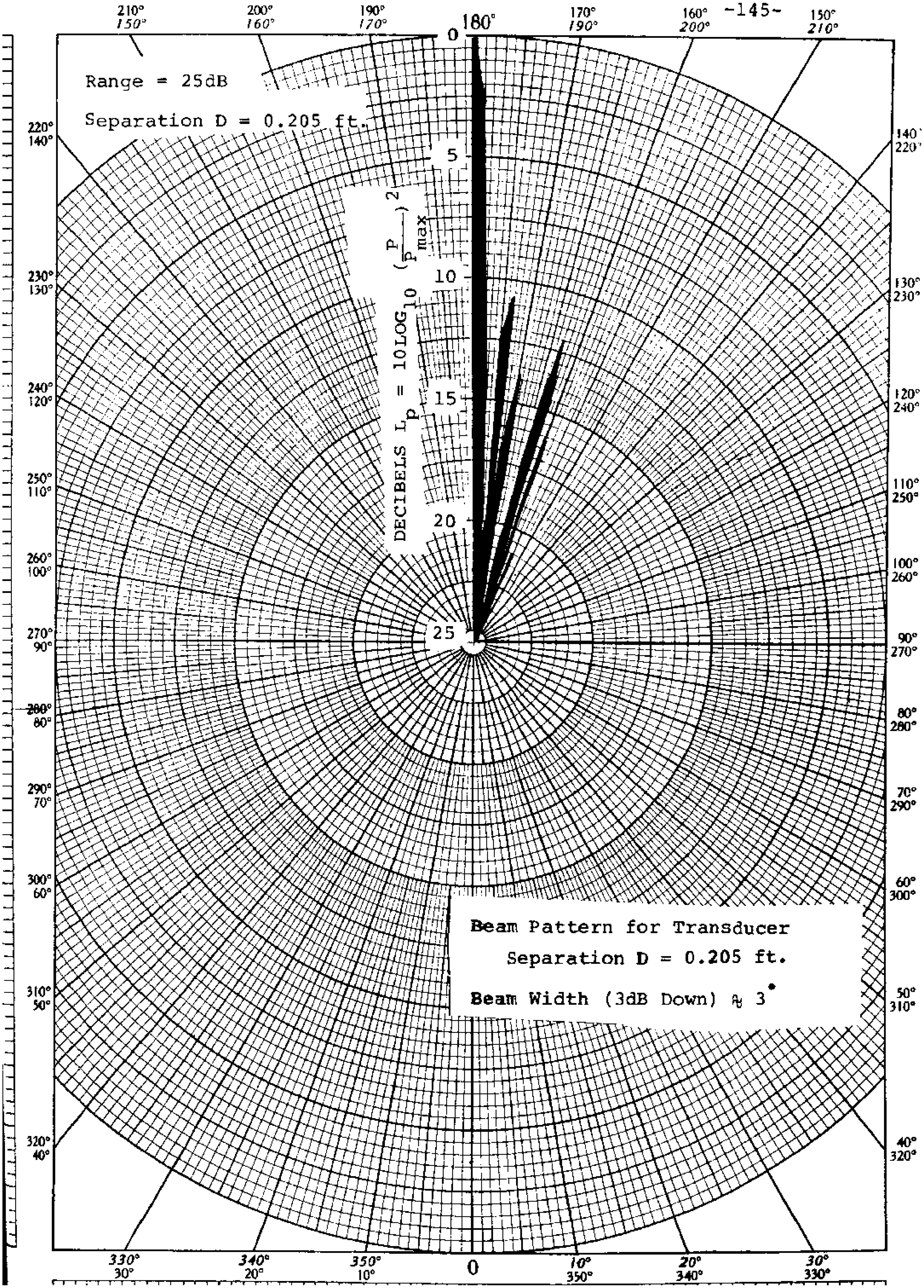


FIGURE 48

The system functioned effectively and allowed us to cover much more area than would have been possible with the bottom sounding mode.

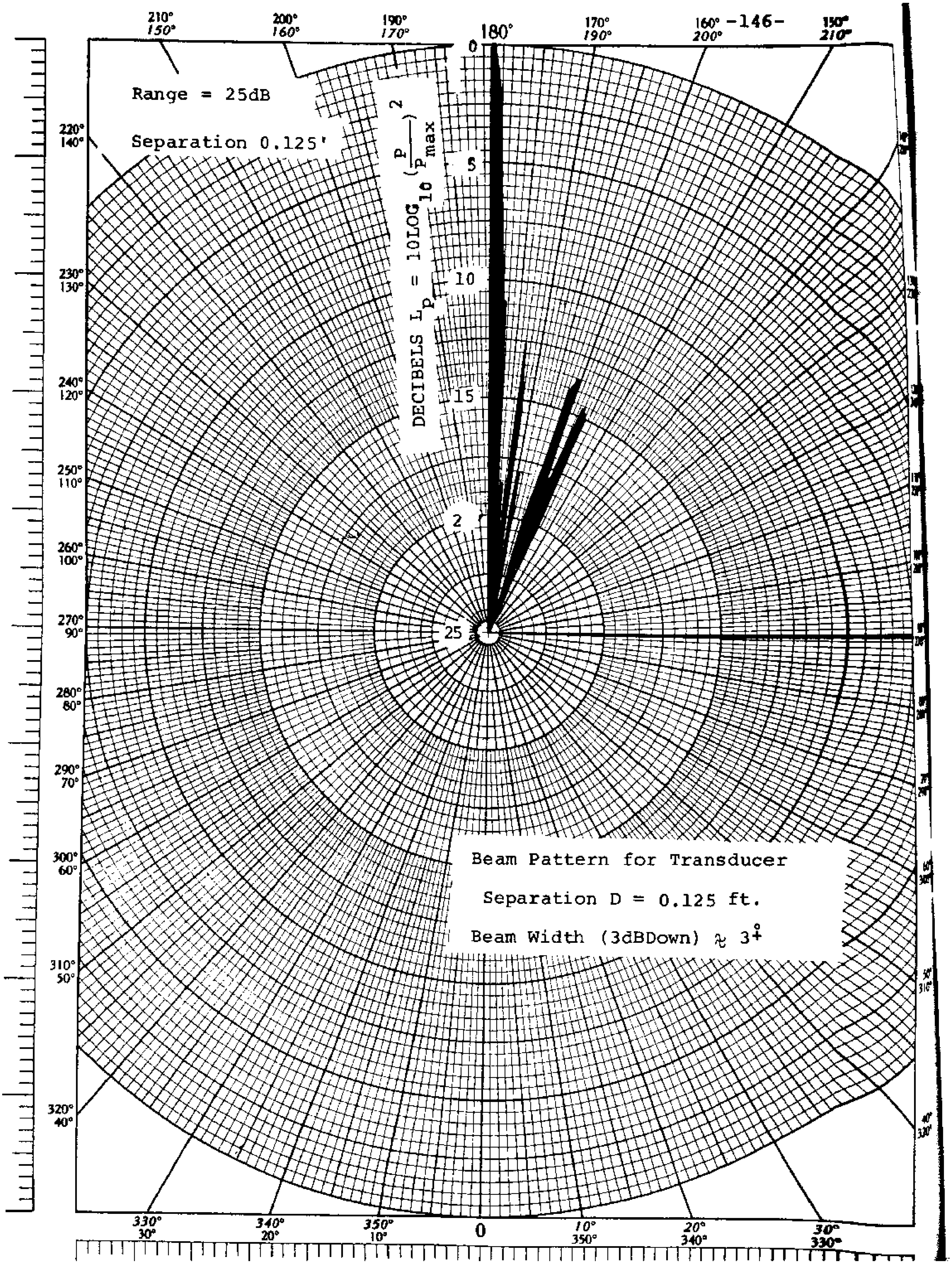


Range = 25dB

Separation D = 0.205 ft.

Beam Pattern for Transducer Separation **D** = 0.205 ft.

Beam Width (3dB Down) ≈ 3°



Range = 25dB

Separation 0.125'

Beam Pattern for Transducer

Separation D = 0.125 ft.

Beam Width (3dBDown) ≈ 3°

GRAPNEL

To simplify the procedure used in the search for the sailboat, we decided to use a grapnel. Previously, whenever a target was sighted on sonar, our only course of action to determine the validity of the target was to send divers down with a circling line to try to locate it. This is a very time consuming operation. By dragging a series of grapnels behind the launch, we would be able to get a physical contact with the target.

The grapnel consisted of an eight foot long two inch diameter hexagonal bar of steel. A ten foot length of chain was attached to each end to keep the bar on the bottom and to keep to a minimum the amount of hopping done by the bar as it was dragged along the bottom. Equally spaced along the bar were four one foot lengths of lighter chain to which were attached the actual grapnels. The grapnels were formed from two foot lengths of 5/16" round steel stock. These were then bent in half to form an angle of approximately 60°. The ends were then bent to form hooks. These hooks ran in opposite directions and were perpendicular to the plane formed by the 60° angle. We decided that it would be a good idea to know when we hooked something to make sure that no harm would be done to the dragging boat. The actual hauling lines were two 130 foot lengths of one inch diameter manila line.

To provide the above indication of hooking something, we put a 20' loop into the towing line approximately 40 feet from the bitter end. It was attached by tying the loop closed with a short length of lighter line. Attached to the end of the loop closest to the boat was an empty plastic bottle on a line that kept it underwater until the loop broke due to the bottle would surface.

While in use with the sonar we found that we could predict when the grapnel would snag the rock outcroppings that we saw on the sonar readout. Also, since we were towing very slowly to allow us to use the sonar, whenever we did hang up, we were moving slowly enough such that the halyard attachments at the loops never broke.

Robert Powers
13.90
September 1971

SCUBA TRAINING COURSE

The scuba training program was a basic YMCA-NAUI course instructed by Professor David Michael of M.I.T.'s Physical Education Department. In addition to the standard instruction, additional drills in the use of tools and mechanical assembly procedures were included. The open-water dives at the conclusion of the course concentrated on evaluating the instruments produced by the program to gather data, underwater search techniques, and underwater skills of the divers themselves.

During the course and the succeeding month in Maine, the difficulty of relying on diving skills for tasks that might be avoided by better design was repeatedly emphasized.

All dives during this period were in 80' of water or less. With only two exceptions, the divers are competent to work in water up to that depth and have had considerable exposure to problems involving instrumentation and underwater moorings.

Jack Price
September 1971

DIVERS TRAINING FOR UNDERWATER WORK

FIGURE 49

DIVING BOARDING LADDER

Introduction

Diving safety depends upon the training of divers and the ease of operation of each dive. Ease of operation is a consequence of careful planning and complete supervision and the use and maintenance of good equipment. Each dive should be planned to minimize the necessity for heavy exertion by divers, which includes working underwater and getting into and out of the water. Conscientious divers generally take care to assure that their air supply system is in good working condition; tanks regulators and compressors get a thorough going over. Diving boarding ladders are anscillary pieces of equipment which rarely curtail diving operations, yet, a bad ladder can make an enjoyable dive into a chore and lead to situations that can endanger a diver. The consequence of discussions with various experienced divers is a boarding ladder which was designed, built and used during the M.I.T.-M.M.A. Ocean Engineering Laboratory in July of 1971.

Design Considerations

The criteria for boarding ladder design follow from performance requirements and compatibility with the diving boat.

Considerations:

1. Length - a ladder must extend through the surface to a comfortable and safe depth. When a ladder is too short

it is difficult to climb and dangerous in a seaway. Usually a diver has to be lifting himself out of the water when he is stepping onto the ladder. At this juncture he is vulnerable to wave forces and heaving boat motions. If he does not fall off the ladder there is the ever present danger of being struck by the heaving ladder while approaching it.

2. Flexibility - A ladder must be rigid. If a ladder is flexible, the diver cannot anticipate its motion and climbing out of the water becomes as swinging on a trapeze. Proper body position cannot be maintained on a flexible ladder. When a scuba diver leaves the water at the end of a dive, he is tired and must carry out all his diving gear. If his body is not at a good attitude the diver's arms must support a considerable load as he climbs out over an overhang. A good ladder, therefore, must be rigid and have a tread at a comfortable slope.

3. Support - A ladder must extend inboard enough to provide support for the diver until he is fully inboard. Poor ladders only aid the diver out of the water. Assisting tenders are then often required. These additional persons usually only confuse the scene and make it difficult for the diver to report to the diving supervisor directly upon entering the boat. Without the continued support from a diving ladder, the potential for an accident increases.

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4. Performance

The dive boat must be able to move between two dive sites at a reasonable speed. Therefore, the ladder must be removeable from the water. However, if the ladder is to provide the rigidity and support desired, it, out of necessity, becomes a permanent fixture on the boat. Hinging the ladder at the water enables the lower submerged section to be folded back on the upper section and removed from the water.

5. Compatibility

Structural differences between dive boats preclude a universal boarding ladder design. For example, for a diving ladder mounted on the transom, the slope of the transom and the freeboard at the stern dictates the length of the bracing struts and the number of treads required while the camber across the stern dictates the shape of the fenders used to keep the bracing from marring the transom. Each dive boat should be equipped with the appropriate struts and fenders.

Design

The ladder which was designed, fabricated and used during the July 1971 Ocean Engineering Laboratory is depicted in Figures 50 and 51. The ladder was deployed on a 34' utility boat belinging to the Marine Maritime Academy of Castine, Maine.

FIGURE 50

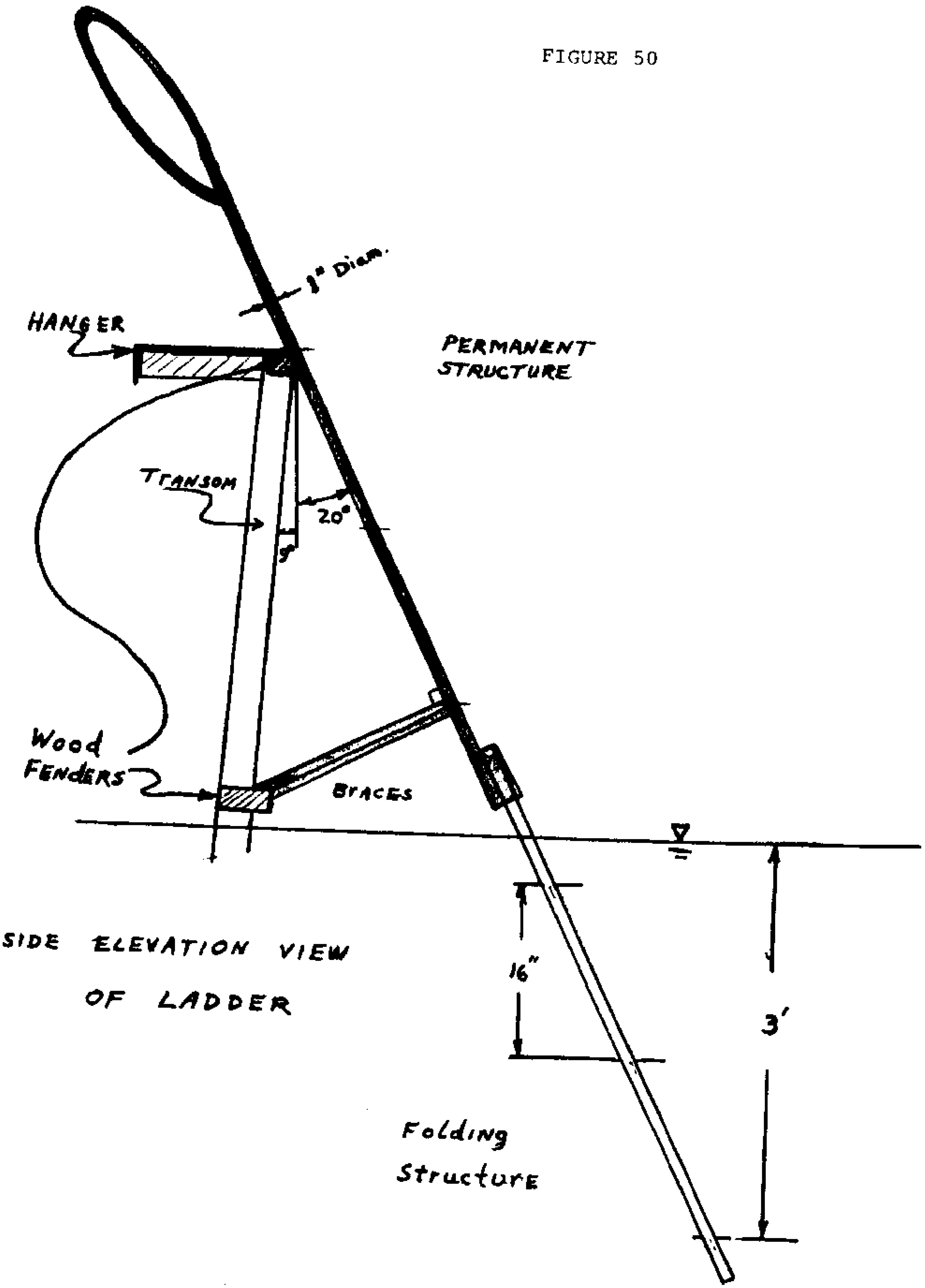
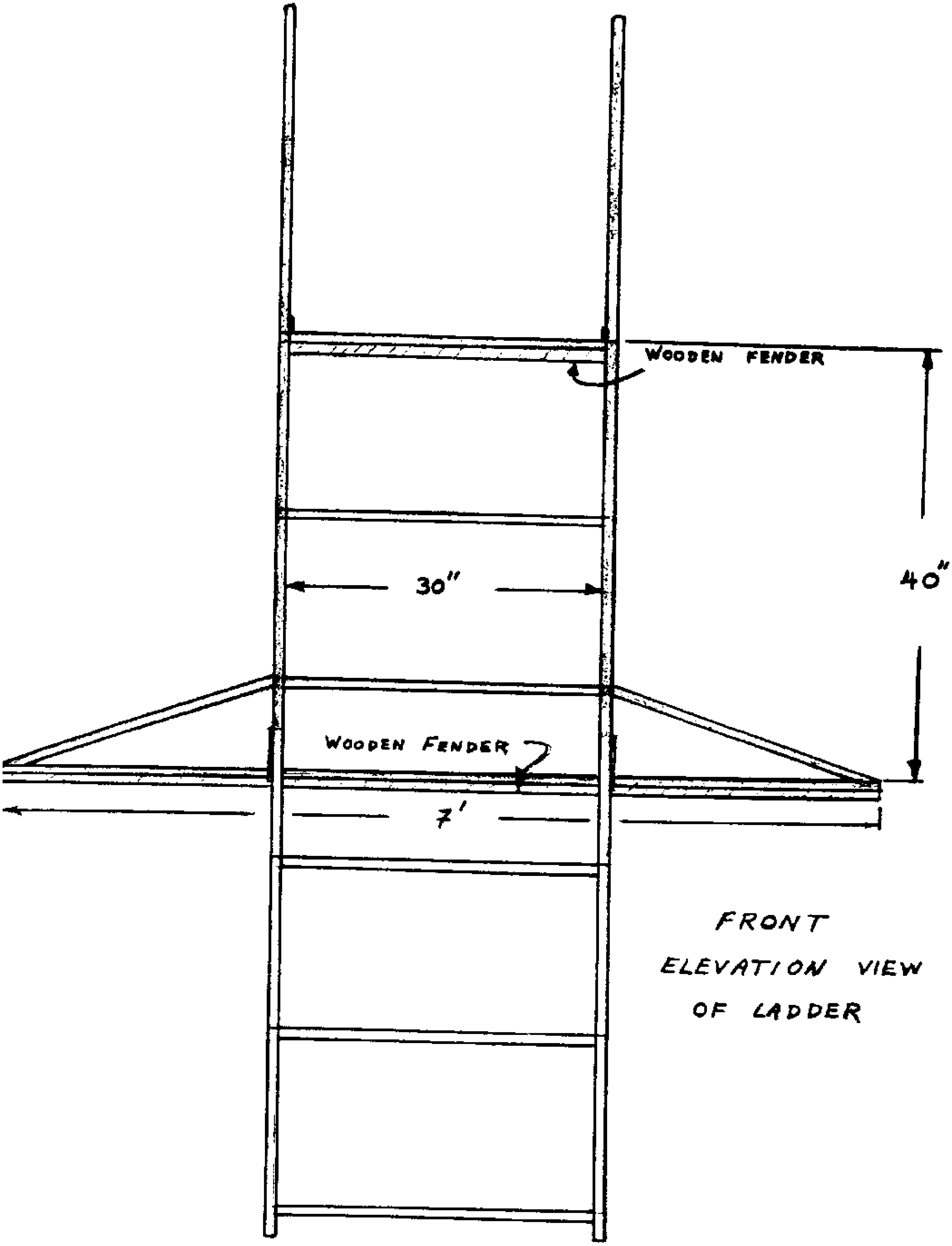

1" Diam.
HANGER
PERMANENT
STRUCTURE
TRANSOM
20°
9°
Wood
FENDERS
BRACES
16"
3'
SIDE ELEVATION VIEW
OF LADDER
Folding
Structure

FIGURE 51

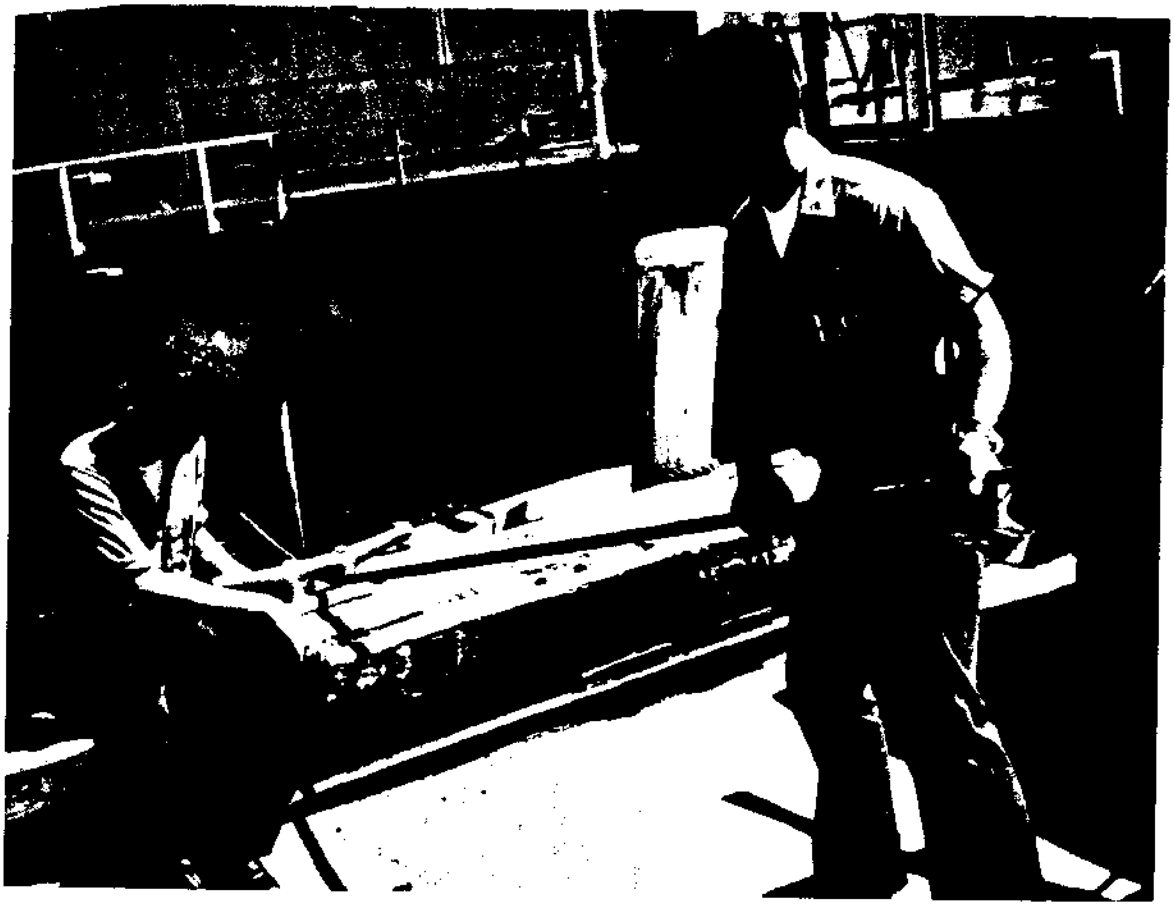

WOODEN FENDER
40"
30"
WOODEN FENDER
7'
FRONT
ELEVATION VIEW
OF LADDER

Components:

1. Handrail - 3/4 inch pipe, which has an O.D. of one inch, was used for the railing. It could be used as the structural member of the ladder and, yet, was of small enough diameter to be comfortable to hold even while wearing gloves. The extension above the gunwale aids the diver in maintaining his balance as he climbs to the bottom of the boat and reports to the diving officer. Note that the extension was bent over to blunt the end and remove the danger of injury.

2. Tread - The treads were designed quite deep, so that heavy loads could be carried up and down the ladder without foot discomfort. Each tread is 3 inches deep, 30 inches wide and 1/8 inch thick. For structural rigidity 1 inch flat stock was used to construct a T-beam at each ladder rung. The treads were separated by 16 inches vertically, a comfortable step even wearing flippers. Six treads were necessary to locate the bottom rung of the ladder three feet below the water surface. From that depth, an easy climb out of the water (rise on run was 2.75) results.

3. Braces and Fenders - In order to position the ladder on the boat, hangers were required to hold the vertical load while the hanger and braces provided the moment necessary to keep the ladder away from the transom. Fenders made of wood covered with cut fire hose protected the curve of the transom from marring by the ladder structure and braces.



BOARDING LADDER CONSTRUCTION

FIGURE 52

4. Folding Bracket - A hinge was constructed which would let the lower part of the ladder fold back on the upper part. By extending the upper part beneath the lower, the submerged section was constructed primarily of mild steel which was welded into the desired shape. In order to protect it from salt water corrosion, the ladder was given three priming and one finish coat of paint. Sand was spread on the rungs of the ladder while they were still wet in order to produce a nonslip surface.

Conclusions and Recommendations

The ladder worked exceptionally well. It was very comfortable to use. There were no difficulties approaching or climbing the ladder. The wide tread and wider boat brace help a diver maintain balance even when the boat was rolling.

Deployment and retrieval of the ladders lower section was simple with the aid of a long boat hook. A potential danger was noted. When the first person climbs the ladder, after its deployment, he should assure himself that the ladder is indeed folded out. Were it not, a hand could get severely cut when placed high on the folding part and weight applied to unfold the ladder. A recommendation would be to secure the lower leg folded out by the use of a pin or spring line.

The mild steel ladder built was already showing signs of stress corrosion at welds after 24 hours in the water.

Whenever possible such a ladder should be made of a light weight, strong material which will not readily corrode in the sea. For example, marine aluminum would be ideal. Thus, protective painting could be eliminated.

Gray Curtis
September 1971

DECOMPRESSION CHAMBER

The only decompression chamber available for use in the vicinity of Penobscot Bay is at the Naval Ship Yard at Kittery, Maine. For our purposes, this represented a 4-5 hour trip in the event of an emergency. Something better was needed.

The University of New Hampshire had available from their Edalhab Project a portable decompression chamber which was at Woods Hole, but which could be made available. An inspection of the chamber showed it to be usable and suitable for our requirements.

The chamber was actually one and a half propane tanks welded together and placed on a trailer bed which can then be towed. The extra half tank serves as a lockout chamber for the main section.

INSTALLATION OF DECOMPRESSION CHAMBER

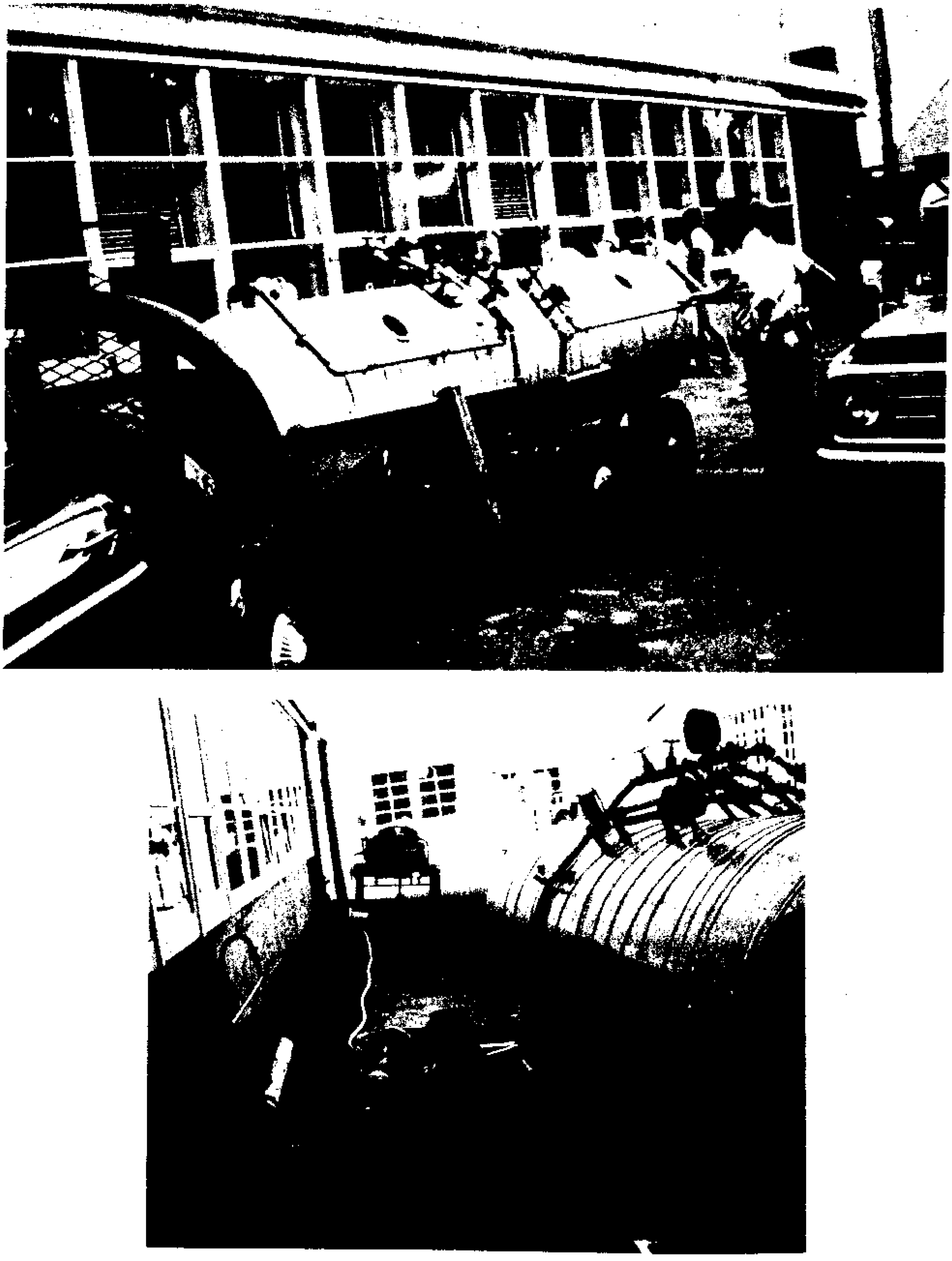


FIGURE 53

Decompression Chamber (con't)

Air pressure for the chamber is provided by a commercial compressor which is tested by the State of New Hampshire for air quality.

Arrangements were made to have the chamber hydro tested to 150 PSI, provided with necessary support items, and delivered to Castine, Maine, prior to the beginning of diving operations. Consideration was given to the possibility of utilizing an oxygen system in conjunction with the chamber. This was not done due to the recommendations of Captain Searle (USN, Ret.) who felt that we might be introducing more problems with an oxygen system than would be justified. We concurred with this recommendation based on the fact that there would be no diving medical officer on site, we would be doing no saturation or even decompression diving, and we intended to use the chamber only as an emergency measure.

The nearest diving medical officer was located in Portland, Maine. Coordination was made with the USCG Search and Rescue Branch to provide on-call helicopter support out of Otis AFB on Cape Cod in the event of an emergency. Within 2 hours of an alert, a diving medical officer would have been on station at Castine.

With the type of diving that we were doing and the experience level of the divers, we felt that our most probable accident would involve embolism. With this in mind, we pressurized the chamber to 165' prior to leaving for dives. The delay in bringing the chamber to a lesser pressure would be less than the time required to lock a diver in through the entry lock. However, should the chamber be at too low a pressure, we would have had to bring both the main and lock-in chambers up together, with the subsequent delay.

We insured that sufficient personnel were competent in the operation of the chamber to provide operators at all times. The chamber was inspected daily for service ability.

There were no incidents requiring use of the chamber during the course of the project. Local USCG officials were notified that the chamber was operating and available for use of the general public in that area should a need arise.

Jack Price
September, 1971

APPENDIX A

Charts

1. Upper Penobscot Bay
2. Cape Rosier-Isleboro
3. Goose Cove
4. Description of Station Locations

DESCRIPTION OF STATION LOCATIONS FOR JULY 25, 1971 SURVEY OF PENOBSCOT RIVER

Station #	Location
1	500 yds. south of southern most point on Verona Island.
2	500 yds. east of non "4", which is .65 naut. mi. east of Sandy Point and .6 naut. mi. SW of southernmost point on Verona Island.
3	Halfway between can "3" and nun "4" or .55 east of southernmost point on Sandy Point.
4	Midchannel, directly beneath center span of bridge between west bank of Penobscot River and Verona Island.
5	750 Yds. north of Fort Knox or 125 yds. SE of main building of St. Regis Paper Mill.
6	350 yds. WNW of station 5 (20 ft. off primary waste outfall of St. Regis Paper Mill.
7	Opposite bank of river from the outfall 50 ft. offshore, beneath overhead power cable.
8	.25 naut. mi. upstream from marina at Winterport.
9	100 yds west of center of bridge between Verona Island and Bucksport.

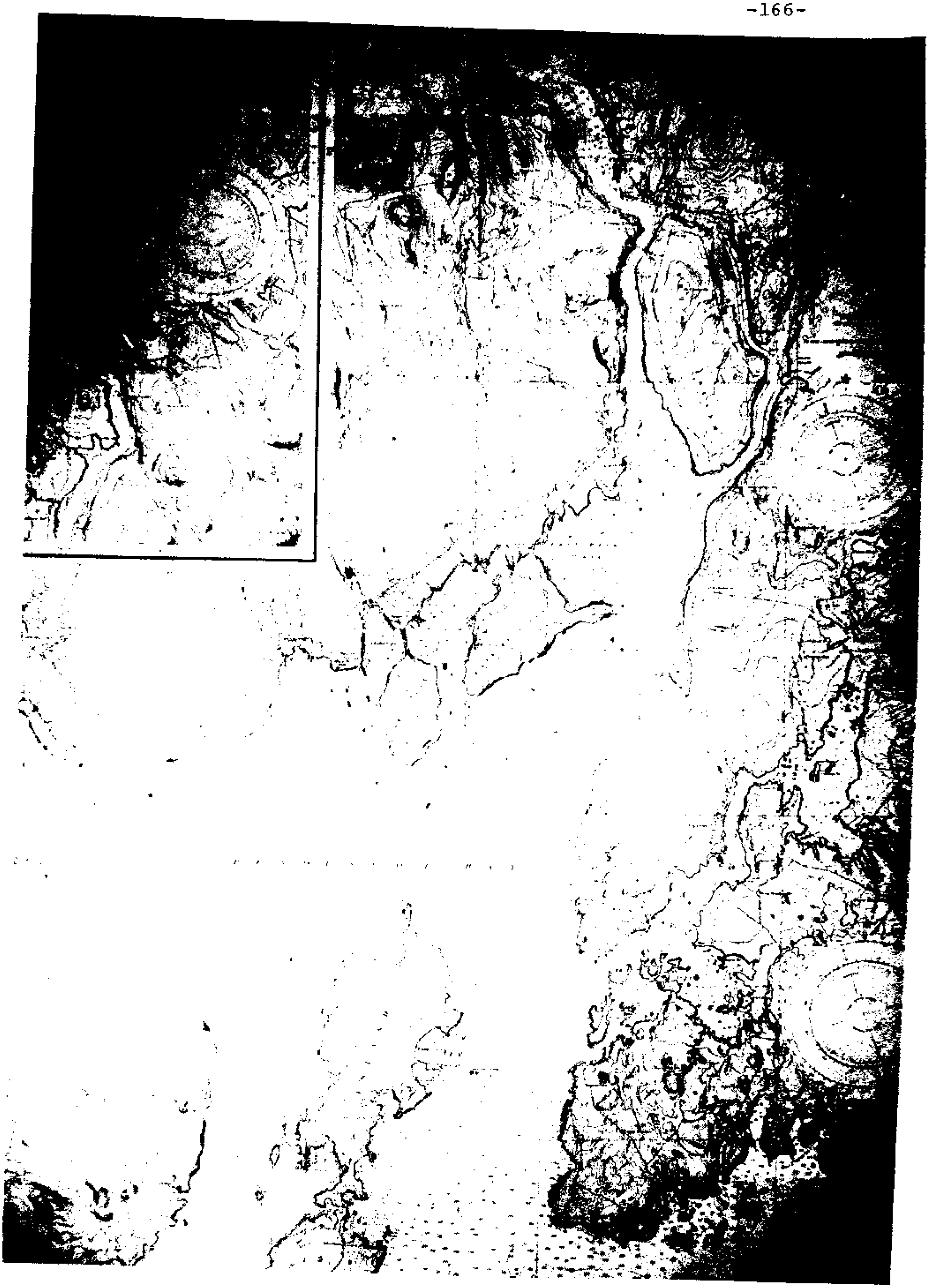


FIGURE 54

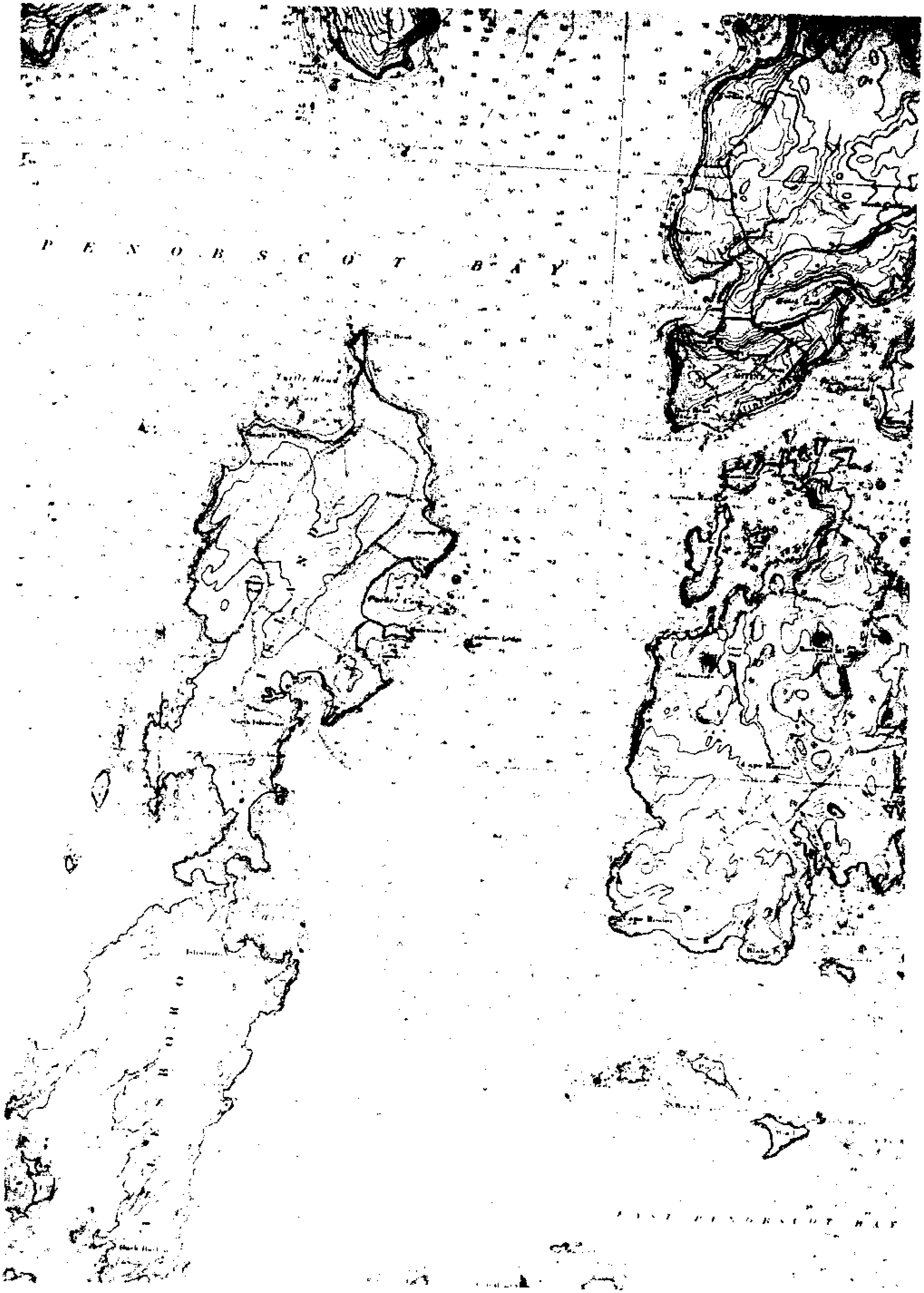


FIGURE 55

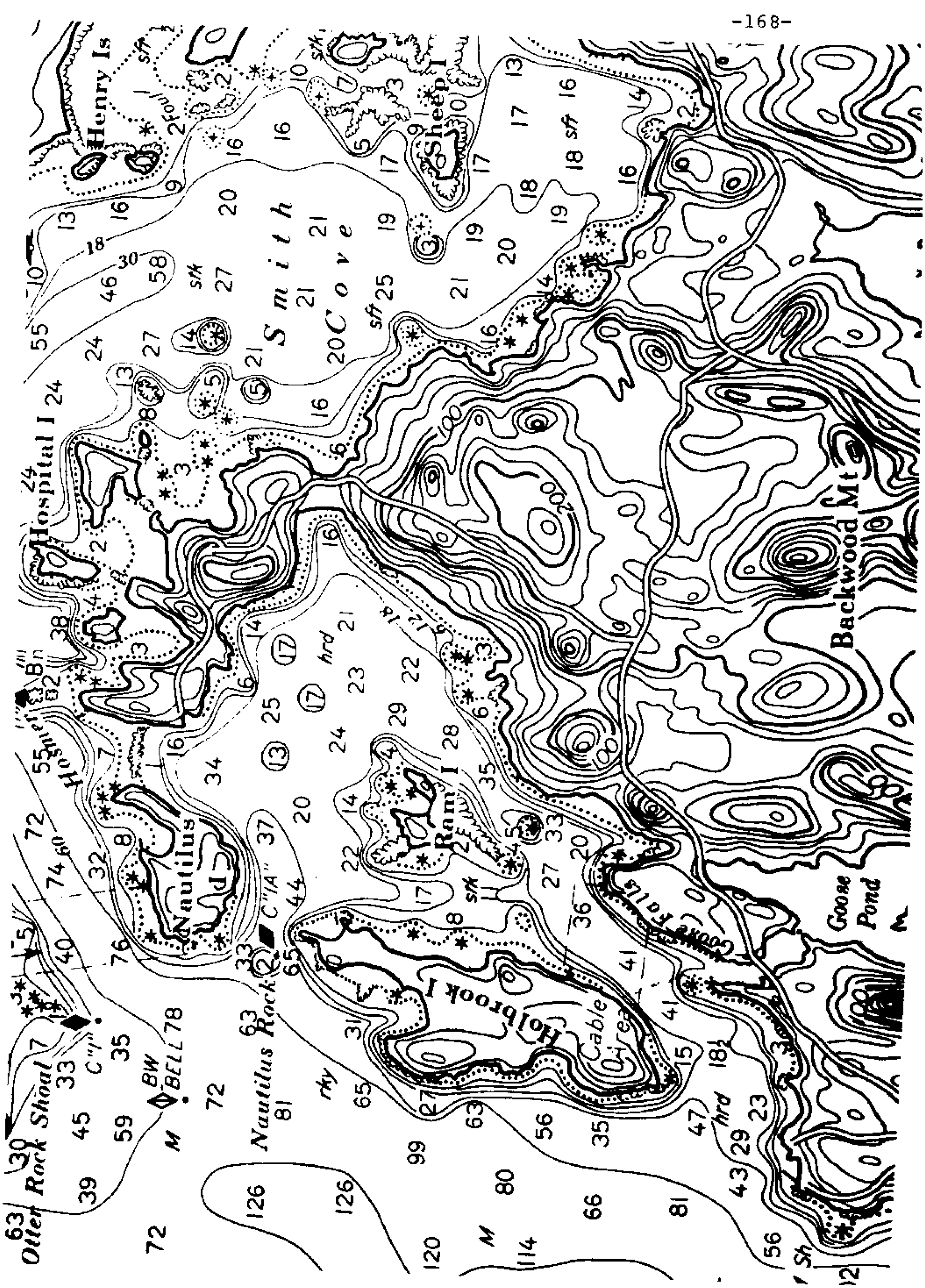

Henry Is
Sheep I
Smith Cove
Hospital I
Nautilus I
Ram I
Holbrook I
Cable Area
Goose Falls
Goose Pond
Backwood Mt
Otter Rock Shoal
Nautilus Rock
BW BELL

FIGURE 56

APPENDIX B

M.I.T. SCUBA DIVING STANDARD OPERATING PROCEDURE

The purpose of this document is to establish responsibilities and standard procedures for scuba diving operations to be conducted during summer 1971 in conjunction with M.I.T.'s Ocean Engineering Laboratory.

Personnel:

Project Supervisor: Professor Damon Cummings (NAUI-YMCA qualified diver)

Diving Officer: Jack Price   Assistant D. O.: Gray Curtis

Experienced Divers/Safety Divers:

Jack Price
Mel Wolpert
Gray Curtis
One additional from Maine Maritime Academy

Student Divers (YMCA-NAUI qualified):

Mel Wolpert
Paul Shapiro
Fred Horr
Bob Powers
Bob Biles
Bob Luckens
John Shenk
Craig Martin

(Other acceptable qualifications):

Sandra Zamansky

Diver Qualifications:

Only divers certified by formal scuba courses such as NAUI, YMCA, or the U.S. Navy Diving School will dive in this program.

Diving Limitations:

1. No recompression diving (see accompanying chart). Note allowances made for exertion and cold water.

2. Safety diver must be rigged and prepared for immediate entry prior to divers entering the water.

3. For open water dives from the 34-foot launch, a manned chase skiff must be on station.

4. All divers must maintain visual contact with their assigned diving buddy while in the water. As soon as visual contact is lost, a diver must surface.

5. Any diver in the water must wear a flotation vest (both free and scuba).

6. Depth limit is 45 feet for newly qualified divers until further open water checkout dives by diving officer.

Responsibilities During Diving Operations:

Diving Officer: overall responsibility for dive, to include:

- A. Give diving briefing:
  - 1) Assign buddy teams
  - 2) Designate safety man
- B. Supervise dive
  - 1) Equipment checks on divers prior to entry
  - 2) Maintain dive log and repetitive dive sheets on all divers
  - 3) Insure divers flag is visible at all times
  - 4) Direct chase boat activities

C. Post-Dive Activities:

1) Supervise filling of scuba tanks for next day's dive (electric air compressor)

2) Accountability for equipment

D. Final determination of diving conditions and diver capabilities for a given dive.

Safety Diver - be prepared to render aid at direction of the diving officer to any disabled diver. Must be rigged prior to any diver going in the water.

NOTE:

1) The diving officer may delegate temporary responsibility to the assistant diving officer when he feels he should be down with a dive team. This man must then be in the dive launch and assume responsibilities of the diving officer.

2) The above requirements apply equally to Maine Maritime Academy personnel and any diving visitors.

Contingency Plan

Decompression Sickness and Air Embolism:

In the event of the appearance of any symptoms of decompression sickness or air embolism, the diver will be taken to the nearest available recompression chamber (Castine, Maine, Merchant Marine Academy) and treatment will proceed as described on pages 173-179 of the March 1970 edition of the Navy Diving Manual.

The nearest diving medical officer is located at Portland and would be contacted anytime a diver goes into the chamber. (See checklists at end of S.O.P.) Responsibility for operation of the chamber is that of the diving officer, or in his absence, the assistant diving officer.

Preparation for the period in Maine will include a familiarization period for the diving officer at the University of New Hampshire for operation of the recompression chamber.

CHECKLIST FOR DECOMPRESSION SICKNESS

In the event a diver is suspected to have decompression sickness, a diving medical officer will be contacted and given the results of this checklist after the diver has been recompressed. (Treat according to U. S. N. Diving Manual, page 173.)

(1) Ask diver how he feels. Details:

Pain? Where and how bad? Affected by movement? Pressure?

Any bruises?

Mentally clear?

See and hear clearly? Talk? Dizzy?

Complete use of extremities? Weak or numb? Funny feelings?

(2) Results of observing:

Movements normal? Limp or stagger?

Speech clear and sensible?

Can he close eyes and keep balance? Clumsy?

(3) Normal strength?

Test handgrip, situp, pushup, pullup.

(4) Sensations normal?

Hear clearly? Normal vision (far and near, not blurred)?

Check eyes: Dilation with a light, pupils normal and equal? Can he track moving objects?

Check reflexes and ability to feel pinpricks on skin.

(5) Time history of dive and symptom occurance. Action taken to date. Maximum depth and duration of dive.

CHECKLIST FOR SUSPECTED AIR EMBOLISM

Any of the below symptoms should result in immediate recompression to 165 feet or as close as can be achieved to that depth. Symptoms on checklist below are listed in order of increasing seriousness:

(1) Bloody, frothy sputum?
(2) Staggering?
(3) Vision and coordination problems?
(4) Paralysis or weakness of extremities?
(5) Collapse?
(6) Unconsciousness?
(7) Convulsions?
(8) Cessation of breathing?

May also be accompanied by:

MEDIASTINAL EMPHYSEMA

(1) Blueness of skin, lips, fingernails?
(2) Hard breathing?
(3) Shock?

SUBCUTANEOUS EMPHYSEMA

(1) Swelling of neck?
(2) Crackling movement of skin?
(3) Voice change?
(4) Hard breathing or swallowing?

PNEUMOTHORAX

(1) Blueness of skin, lips, fingernails?

(2) Pain in side of chest? Tendency to lean to that side?

(3) Rapid, shallow breathing?

NOTE: Always accompany above information with a time history of dive, symptom occurance, and initial treatment. Include duration and depth of dive.

RECORD OF DIVE

____ JULY 1971

M.I.T. SEA GRANT PROJECT #72599

DIVERS' NAMES	PURPOSE
	DIVING OFFICER
	SAFETY DIVER
	BOAT
	LOCATION

PREVIOUS DIVE WITHIN LAST 12 HOURS: YES ____ NO ____

TIME COMPLETED	____				
DEPTH	____	REPETITIVE		ELAPSED TIME	____
DURATION	____	DESIGNATOR	____	NEW DESIGNATOR	____

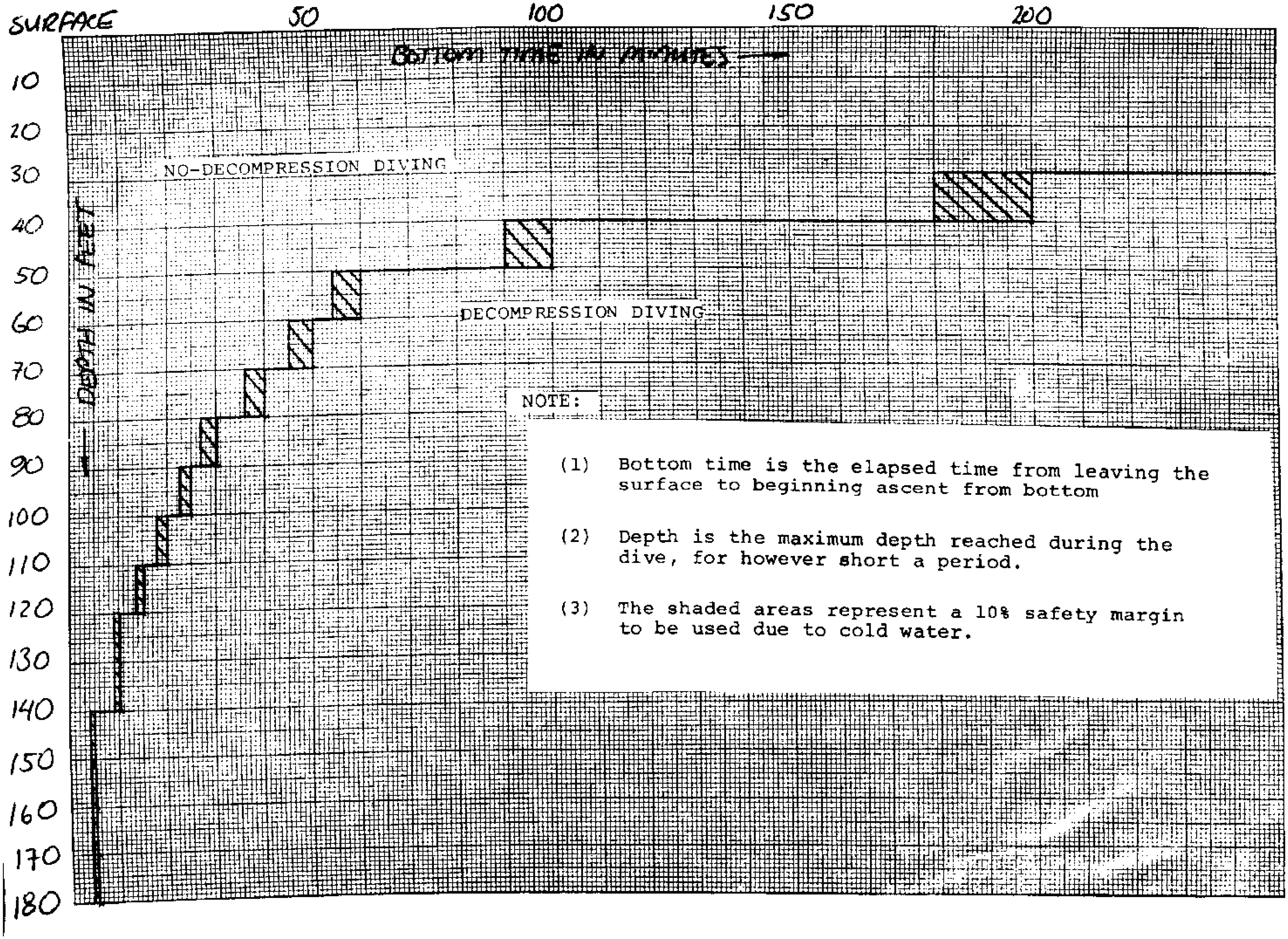
THIS DIVE

REPETITIVE DESIGNATOR COMING INTO DIVE	____	MAX DEPTH TO BE OBTAINED	____	RESIDUAL TIME	____

MAXIMUM DEPTH	____	LEAVES SURFACE	____
NO DECOMPRESSION TIME	____	ARRIVES BOTTOM	____
SAME AS ABOVE MINUS 10%	____	LEAVES BOTTOM	____
SAME MINUS RESIDUAL	____	ARRIVES SURFACE	____
MAX ALLOWABLE BOTTOM TIME	____	ACTUAL MAX DEPTH	____

BOTTOM VISIBILITY ____	ACTUAL BOTTOM TIME ____ + RESIDUAL ____
TYPE OF BOTTOM ____	EQUALS TOTAL DURATION ____
	NEW REPETITIVE GROUP DESIGNATOR ____

COMMENTS



NOTE:

(1) Bottom time is the elapsed time from leaving the surface to beginning ascent from bottom

(2) Depth is the maximum depth reached during the dive, for however short a period.

(3) The shaded areas represent a 10% safety margin to be used due to cold water.

APPENDIX C

DATE-TIME		DIVERS	DEPTH	DURATION	DIVING OFFICER	SAFETY	LOCATION	TASK
07	1040	Lukens-Wolpert	30	64	Price	Curtis	S. of Ram Island	Place Buoys
		Schenck-Biles	25	40	"	"	"	"
08	1013	Martin-Shapiro	40	15	Curtis	Wolpert	Goose Pond II	Place Anchors
10	1125	Wolpert-Schenck	28	30	Price	Price	MMA Dock	Equip Test
10	1350	Cummings-Biles	40	60	Price	Wolpert	Goose Pond II	Place Buoy
		Shapiro-Martin	40	30	"	"	"	"
10	1550	Lukens-Wargo	40	30	"	"	"	"
11	1155	Horr-Biles	70	9	Curtis	"	44°18.2N 68°53.6W	Bottom Searc & Qualificati
11	1151	Price(Instr.)	70	25	"	"	"	"
11	1207	Martin-Decrow	70	9	"	"	"	"
11	1251	Schenck-Zamansky	70-40	12	Price	Horr	"	"
11	1320	Wargo-Powers	70-40	11	"	"	"	"
11	1251	Curtis (Instr.)	70	35	"	"	"	"
11	1445	Wolpert-Martin	40	56	Curtis	Price	Goose Pond II	Service Equi
		Wargo-Biles	"	28	"	"	"	"
12	1203	Wolpert-Decrow	50	8	"	Kunz	Target #2	Bottom Searc
12	1236	Kunz-Horr	70	7	"	Wolpert	"	"
12	1525	Cummings-Powers	40	65	Price	Lukens	Goose Pond II	Service Grou
		Fogg-Zamansky	"	"	"	"	"	"
12	1037	Schenck-Biles	60	8	Curtis	Fogg	$7\frac{1}{2}^{\circ}$ Cape Rosier	Bottom Searc
13	1644	Cummings-Powers-Biles	50	26	Searle	Price	Goose Pond III	Photography
14	0640	Cummings-Martin	40	15	Curtis	Price	Goose Pond II	Service Equi
14	1054	Swinborne-Price	30	17	"	"	"	Qualificatio
14	1134	"	40	55	"	Wolpert	"	"

DATE-TIME	DIVERS	DEPTH	DURATION	DIVING OFFICER	SAFETY	LOCATION	TASK
15 0847	Kunz-Powers	70	11	Curtis	Price	Target #1	Qualification
	Schenck-Biles	70	31	"	"	"	Bottom Search
15 1321	Curtis-Lukens	40	19	Price	Horr	Goose Pond II	Service Equip
15 1508	"	"	13	"	"	"	"
15 1522	Kunz-Shapiro	70	33	"	"	Off East Coast of Holbrook Is.	Recreation & Qualification
	Wolpert-Swinborne	"	"	"	"	"	"
	Curtis-Lukens	"	"	"	"	"	"
	Wargo-Decrow	"	"	"	"	"	"
16 1001	Horr-Biles	35	11	Searle	Alternate Teams	54° Cape Rosier	Bottom Search
	Wolpert-Decrow	"	"	"	"	"	"
16 1040	Kunz-Curtis	"	30	Searle	Horr	Station 6	Bottom Life
	Wolpert-Decrow	"	"	"	"	"	"
16 1456	Fogg-Swinborne	50	40	Kunz	Price	Goose Pond I	Bottom Search
16 1529	Price-Cummings	50	60	"	Fogg	Goose Pond II	Place Equip
16 1701	Shapiro-Schenck	50	21	"	"	"	"
17 0632	Shapiro-Schenck	40	36	Curtis	Price	"	"
19 0812	Price-Cummings	50	74	"	Schenck	"	"
	Martin-Shapiro	"	21	"	"	"	"
20 1019	Biles-Wargo	70	15	"	Price	"	"
	Price-Schenck	"	"	"	Biles-Wargo	Station 3	Bottom Search
21 1120	Martin-Shapiro	40	10	"	Schenck	Goose Pond II	Set Mooring 3
21 1139	Martin Schenck	"	16	"	"	"	"
21 0940	Price-Schenck	70	20	Searle	Alternate Teams	East of Isleboro Island	Bottom Search
	Biles-Swinborne	"	"	"	"	"	"

DATE-TIME	DIVERS	DEPTH	DURATION	DIVING OFFICERS	SAFETY	LOCATION	TASK
21 1613	Price-Milgram	50	55	Curtis	Wolpert & Swinborne	Goose Pond III and IV	Trim Mooring Lines
21 1607	Cummings-Biles	"	56	"	"	"	"
22 1524	Price-Schenck	70	11	"	Alternate Teams	210° to Station 6	Target Check
22 1553	Biles-Wargo	70	18	"	"	"	"
23 0735	Wolpert-Decrow	40	8	"	Horr	11° N. Cape	"
24 0900	Price-Schenck	70	40	"	Wolpert	216° Hewes Pt.	"
26 0950	Shapiro-Martin	50	30	Price	Allen	Goose Pond IV	Move Moorings
26 1340	"	"	60	"	"	Holbrook Channel	Moorings
26 1505	Biles-Allen	60	56	"	Lukens	"	Photography
27 1046	Shapiro-Wargo	10	5	Curtis	Wolpert	Outer Bay	Clear Prop
27 1601	Wargo-Horr	50	50	Price	Shenck	Goose Pond III	Place Equip
28 0643	Wolpert-Fogg	60	20	"	Swinborne	Can 1-A	"
28 0746	Wolpert-Zamansky	40	16	"	"	"	"
	Fogg-Biles	"	"	"	"	"	"

NOTE: Duration times are from entry to exit, but may not mean that the diver was at the indicated depth for the entire period.

SEA GRANT SUMMER PROJECT - 13.90

DAILY LOG

Monday, July 5, 1971

The M.I.T. group met at Professor Cumming's house at 10:00 A.M. to travel to the Maine Maritime Academy at Castine, Maine.

Tuesday, July 6, 1971

After a brief meeting and introduction of the M.I.T. and M.M.A. students, the group broke up into smaller units to work on specific project areas.

Gray Curtis began designing a ladder for SCUBA divers to board the Academy's 34 ft. motor launch.

Bob Lukens worked on his vibrating wire current meter in preparation for a water test.

Paul Shapiro made final adjustments and tests of the styrofoam cup current measuring system.

Mel Wolpert prepared his tidal height meter for water testing.

Jack Price welded mooring supports to his current direciton finder.

Craig Martin tested the circuitry for his propeller driven current meter.

Bob Dwyer, Richard Katz, and Sandy Zemansky took water samples near the academy docks.

Bob Powers made final adjustments on his range finder which was to be used in conjunction with the styrofoam cup system.

Bob Powers and John Schenck travelled to Northeast Harbor to get SCUBA tanks filled, since the air compressor had not yet arrived at the Academy.

Bob Biles, the group's photographer, took pictures of the various activities.

Lt. David Wyman, the man in charge of project activities at the Academy held a barbeque at his house in the evening.

Wednesday, July 7, 1971

Two buoys were placed near Ram Island to mark a channel for the 34 ft. launch. Initial tests for water tightness were made on Martin's current meter, Luken's current meter, Wolpert's tidal height meter, and Price's current direction indicator.

Mr. Robert Blake and Mr. William Miskoe arrived from the University of New Hampshire with the decompression chamber. They assembled the chamber immediately.

The air compressor arrived and was installed. Bob Dwyer did calibrations for salinity measurements and made further oxygen measurements.

Mike Wargo worked on electronics to amplitude modulate low frequencies on higher frequencies. This gear was used initially with the Martin current meter.

A contingent travelled to Bangor for supplies.

It was decided that the photographing of installation of underwater equipment was nearly impossible for two reasons:

a) the extra-buddy team required for photography just confused matters, and

b) working near the bottom stirred up so much silt that the visibility was reduced below that necessary for good pictures.

A frisbee match was held after supper.

Thursday, Friday, and Saturday, July 8-10, 1971

Professor Damon Cummings went cupping to measure currents in Goose Cove, a cove between Holbrook Island and Goose Falls. He also made visibility measurements at the station.

More work was done on the diving ladder.

Fred Horr completed his first electronics support buoy which was later moored in Goose Cove.

Martin's current meter was placed in Goose Cove at the new buoy mooring site.

Jack Price prepared to test his current direction indicator.

The biology group (Dwyer, Katz, and Zemansky) made final salinity calibrations, performed more oxygen content measurements of master samples and sent other water samples back to Cambridge, Massachusetts.

Sunday, July 11, 1971

A qualification dive to seventy feet was done in connection with a search for the Shields sailboat in the area of target number one. The underwater search failed to find the target that was indicated by the fathometer record.

Martin and Wolpert later made a dive to adjust the buoyancy of Martin's current meter. However, Martin decided (after the work failed to produce the desired results) to remove the meter back to the laboratory at the Academy so he could make further adjustments.

Monday, July 12, 1971

Captain William Searle and Lt. Cmdr. Herman Kunz, retired Navy salvage men, arrived at the Academy to assist in the search for the lost Shields sailboat during that week. They immediately set out with the group for the day's search Several fathometer targets were again found; however, a visual search by the divers failed to turn up anything.

Paul Shapiro, Jack Price, and Bob Lukens motored to Bangor to buy anchors and line.

Shapiro and Martin attempted to deploy the Martin current meter near the ship's starboard float. When they found that the current was too strong for them to work, they abandoned the attempt.

The mooring lines of the Goose Cove buoy were replaced with better rope.

At an evening meeting of the project participants, it was decided that a drag bar with several grapples attached should be built to use in the Shields search. Captain Searle and Cmdr. Kunz expressed approval of our search methods, considering the limited equipment we had available.

Tuesday, July 13, 1971

The search group left for station #6 on Isleboro Island at 5:00 A.M. and returned at 12:00 P.M. unable to report any success.

Fred Horr's second instrument support buoy was moored in Goose Cove.

Jack Price found that his current direction indicator needed more buoyancy. A net was knitted to hold and support a plastic garbage bag float to be inflated with air and act as a float.

Craig Martin built a gimbal arrangement to hold his current meter parallel to the water flow.

Mel Wolpert removed the electronics from within his meter to a surface box, so that the circuit would have less chance of being shorted out.

A film concerning ocean engineering was shown at the evening meeting by one of the guests.

Wednesday, July 14, 1971

Foggy weather forced cancellation of the sailboat search. However, a small group of divers searched unsuccessfully for a lost mooring in an area of the yacht club.

Most project participants spent the afternoon sailing on the Gemini (a 50 ft. M.M.A. sloop) under the direction of Gardiner Fogge.

Bob Lukens built a double-cam-operated timer for the tape recorder clocks.

Craig Martin and Paul Shapiro made further adjustments on Martin's current meter.

The 34 ft. launch was loaded for Thursday's sailboat search.

A meeting of the Green Safari Rangers was held later in the evening.

Thursday, July 15, 1971

The early morning Shields search failed to provide any new clues as to the sailboat's whereabouts

The new grappling bar rig was successfully tested off Holbrook Island in the afternoon.

The biology people made current measurements with the styrofoam cups.

A pleasure dive took place off the western shore of Holbrook Island.

A meeting to plan the Friday search and diving activities was held after supper.

Friday, July 16, 1971

Transit courses were run by the launch from Station #6 towards Cape Rosier and towards the marker buoy at Isleboro Ledge in the morning. The fathometer worked well - indicating rocks upon which the grapple in tow later hung up. Nevertheless, still no sailboat. Divers were used to search the areas where the grapple got caught and to free the grappling hooks from those obstacles.

An eventful afternoon was spent at Goose Cove. Jack Price flooded his current direction indicator because he failed to clear the pressure equalization hose of water before he attempted to equalize his meter case. Paul Shapiro lost, but later found his weight belt. John Schenck failed to find his weight belt after he lost it. And to top off the day, Professor Cummings was climbing up the diving ladder when his tank with regulator attached slipped from his back pack to the sea bed. Search for the tank was postponed until Saturday due to the lack of air.

Saturday, July 17, 1971

An early morning search at Goose Cove turned up Cumming's lost tank and regulator.

The new diving ladder was used for the first time by this dive. All the divers found it an excellent improvement over the rope ladder with wooden steps that had been previously used.

An interesting sidelight is the saying that Jack Price used when questioned about the status of our sailboat search, "We find just about everything we lose."

Sunday, July 18, 1971

Even though Professor Cummings declared the day a mandatory holiday, the following work was done: A group went up the Penobscot River to take water samples; Jack Price calibrated his current direction indicator, and Craig Martin and Paul Shapiro soldered broken connections in the current meter electronics.

Monday, July 19, 1971

Jack Price placed his current direction indicator near the buoy moored in Goose Cove.

A late afternoon search for the sailboat with Dr. Ira Dyer proved disappointing. Of the problems that occurred here, the major ones were that the grappling rig lines were tangled, a walkie-talkie had a jammed antenna, and to top things off, the sea state and resulting wet deck of the boat made work especially precarious.

Dr. Dyer explained at the evening project meeting that most of the targets on the fathometer recordings were only fish.

Tuesday, Wednesday, and Thursday, July 20-22, 1971

The sailboat searchers of each morning found no sailboats. A rocket like fathometer transducer tow was built and the transducer was rotated for use as a crude side scanning sonar rig. The rig towed very well even at speeds in excess of 6 knots.

A wednesday afternoon sailboat search was fruitless.

Thursday afternoon (the 22nd) a dive was made on the current direction indicator and on Martin's current meter. The current meter was again dry docked for repairs.

Friday, July 23, 1971

Heavy fog caused postponement of the sailboat search. The expedition finally left at 10:00 A.M. to test the new sonar on boat runs between Station #3 and Hene's Point. Still no luck.

In the afternoon, Paul Shapiro and Craig Martin reinstalled Craig's current meter. Professor Cummings and Professor Milgram attached the indicator vane to Price's current direction indicator.

Two M.M.A. students began work on a Savonius rotor current meter.

Sunday, July 25, 1971

A group took water samples in the Penobscot River between Castine and Bangor, using the newly relaunched 50 ft. "yacht."

Monday, July 26, 1971

The side looking sonar was further modified by placing a pair of transducers end to end to narrow the fore and aft sonar beam angle. Craig Martin's current meter was moved to the channel between Holbrook and Nautilus Islands. Pictures were taken of the current meter and the current direction indicator by Bob Biles and Steve Allen. The new double transducer was tested around "Debbie" (Price's inflated green garbage bag monster) with dubious results.

A meeting was held at the gymnasium followed by a series of volleyball games.

Tuesday, July 27, 1971

The morning sonar test revealed that the double transducer rig needed adjusting. Jack Price's current direction indicator was taken from the water for good, but his instrument buoy was moved to the channel between Holbrook and Nautilus Islands.

The day presented itself with much fog and many weary faces.

Wednesday, July 28, 1971

The 50 foot work boat began sailboat searching early in the morning off stations three and six. Meanwhile, the diving crew of the 34 foot launch installed the new Savonius rotor current meter in the Nautilus Island channel. Following the meter installation, the 34 footer and company cruised to Station #6 to assist in the sailboat search, should it be necessary to send divers to a target area. No diving was required and the crew returned to the Academy for lunch.

A recreational dive was made in the afternoon by those divers with enough strength left to make it.

Remarks concerning the project were made at the final evening meeting by Professor Cummings, Dr. Dyer, Lt. Wyman, Gray Curtis, and Jack Price. A slide show of Sea Grant slides was then held.

Thursday, July 29, 1971

The final early morning search was done between Barred Island and Green Ledges. In the afternoon a picnic was held on Rum Island and several teams of divers explored the island's coast line.

Friday, July 30, 1971

The project operations in Maine were wrapped up, the gear packed up and most of the people headed back to M.I.T.

Mel Wolpert
13.90
September 1971